

## Posters

### **The singular limit of a chemotaxis-growth system with general initial data**

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We study the singular limit of a system of partial differential equations which is a model for an aggregation of amoebae subjected to three effects: diffusion, growth and chemotaxis. The limit problem involves motion by mean curvature together with a nonlocal drift term. We consider rather general initial data. We prove a generation of interface property and study the motion of the interface. We also obtain an optimal estimate of the thickness and the location of the transition layer that develops.

### **Effective medium theory for heterogeneous reaction-diffusion systems**

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Waves and fronts propagate in nonlinear spatially extended systems. Normally extended systems present heterogeneities and deformations which hinder the stable propagation and which cannot be avoided. Numerical models usually do not consider any type of defects and they study homogeneous models. Here we study the propagation of a front in a bistable and in an excitable medium for two different types of defects: some sites of the numerical grid do not propagate the front (site percolation), or some connections between the sites do not propagate (bond percolation). Partially propagating defects are also considered. We calculate the velocity of both situations for different densities of defects, and compare the results with an effective model theory.

### **Properties of fingering patterns measured by Gradient Pattern Analysis**

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The interface between two miscible fluids can become unstable when a more mobile fluid displaces a less mobile one. This is the case in viscous fingering when a less viscous fluid pushes a more viscous one and in density fingering (due to a so-called Rayleigh-Taylor instability) when a more dense solution lies on top of a less dense one in the gravity field. Here, the complexity of the resulting spatial deformations of the interface is characterized in both cases by a Gradient Pattern Analysis (GPA) technique which quantifies the lack of symmetry and the spatial fragmentation of the fingering pattern in the course of time. The similarities and differences in the dynamics between density and viscous fingering are discussed using GPA which is able to diagnose transitions in the formation process and in the nonlinear dynamics of fingers.

## **Altered structure of the cerebellar granule cell layer of mice lacking calretinin**

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Calcium binding proteins, such as calretinin, are abundantly expressed in distinctive patterns in the central nervous system, but their physiological functions remain poorly understood. Calretinin is highly expressed in cerebellar granule cells and calretinin deficient mice exhibit alterations in motor coordination (Schwaller et al., 2002). Using confocal microscopy, we demonstrate that the cerebellar cortex of calretinin deficient mice exhibit a significantly decreased granule cell density. Interestingly, it has been shown that the migration of granule cells is tightly associated with intracellular calcium oscillations (Komuro et al., 2005). Therefore, we hypothesize that the modification of these calcium oscillations in calretinin deficient mice could be involved in the observed morphological alterations. To test this assumption, we are currently developing two strategies. First, using confocal microscopy and cerebellar microexplant culture, we are studying calcium oscillations occurring during granule cell migration in the wild type control and calretinin knock-out mice. This allows us to characterize the impact of variations in calcium buffering capacity over neuronal development and on the generation of the calcium oscillations observed during the granule cell migration. On the other hand, using a similar approach as a previous study (Roussel et al., 2006), we are developing a theoretical model based on the De Young-Keizer (1992) mathematical model for  $[Ca^{2+}]_i$  oscillations. This dedicated computational model will shed light on the possible mechanism responsible for the modulation by calretinin, of calcium oscillations during the granule cell migration.

De Young G. W. et al. (1992) PNAS, 89(20):9895-9.  
Schwaller B. et al. (2002) Cerebellum, 1(4):241-58.  
Komuro H. et al. (2005) Cell Calcium, 37(5):387-93.  
Roussel C. et al. (2006) Cell Calcium, 39(5):455-66.

## **The optical monitoring of glycolytic oscillations in immobilized yeast cells**

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The viability of immobilized yeast cells was determined by monitoring the fluorescence intensities of biogenic fluorophores (f.e. NAD(P)H) during aerobic-anaerobic transition. The NAD(P)H also corresponds the metabolic pathway as glycolytic oscillations. In collaboration with the Otto von Guericke University in Magdeburg (Germany) we have measured the glycolytic oscillations of immobilized *Saccharomyces carlsbergensis* ATCC 9080.

## **On the motion of micro-particle swarms in a concentration gradient**

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The ability of both single-cellular and higher organisms to actively move in the concentration gradient of a signalling molecule – whether to seek a source of nutrient or a partner to mate – is one of the most prominent external signs of life: “it moves, hence it must be alive!”. Mimicking chemotaxis in artificial or

bio-artificial systems is a challenging task; usually the objective is to devise a bio-mechanic apparatus such as a flagellum in order to ensure active propulsion. However, chemotaxis based on such bio-mechanic principles still remains an elusive task. In this work we will present a different approach to achieving chemotaxis in artificial protocells (i.e. simple, synthetic particles possessing one or more functions of real cells). This approach, which we term 'probabilistic chemotaxis' is based on the combination of random Brownian motion and specific particle-substrate interaction, the strength of which is designed to be a function of the concentration of the desired signalling molecule. Provided that the interaction is reversible, the repetition of adhesion-release events leads to a bias random walk, whereby a swarm of proto-cells gradually migrates in the direction of the concentration gradient. We will present computer simulations and experimental data demonstrating this chemotaxis mechanism, and discuss the potential for its further development, in particular the signal amplification and cooperative behaviour due to cell-cell signalling.

## **Structuration of phytoplankton communities by lateral stirring**

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Plankton patchiness is one major obstacle to the use of simple models for describing the ecological dynamics of real marine communities. The origin of such patchiness is twofold: on the one side, the ecological processes of competition and substitution, also visible in a homogeneous setting; on the other side, the spatiotemporal dynamics of the water masses, dictated by the physical laws of a moving fluid. Here, we combine a method for extracting transport barriers from altimetry data [Lehahn et al. 2007] and an algorithm (Physat, [Alvain et al. 2004]) for identifying planktonic groups from sea water color measures. In a case study from the South Atlantic, we show that it is possible to link transport barriers arising from horizontal stirring to the spatial repartition of planktonic groups in the course of a bloom. Moreover, the analysis of back-trajectories can be exploited for reconstructing the history of a predominant group and its putative origin, thus providing informations relevant for the ecology and conservation of marine food webs.

## **Cytoskeletal filament length regulation by length dependent depolymerisation rates**

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Unregulated polymer assembly typically leads to exponential length distributions. In living cells, though, the length distribution of cytoskeletal filaments often shows a sharp maximum at finite value. Examples are given by microtubules in the mitotic spindle or actin filaments in muscle fibres. This indicates that filament lengths in cells are regulated.

We discuss a simple mechanism of length regulation, based on proteins that influence detachment rates of filament subunits. We analyze steady state distributions by Monte-Carlo simulations and develop a method to analytically characterize their key properties. Depending on parameters, we find 3 different types of behavior: 1) unbounded filament growth, 2) exponential distributions, and 3) unimodal distributions. Distributions of the latter type can be very sharp with a standard deviation that is much smaller than the mean filament length. We discuss our findings in the context of cytoskeletal filaments in living cells.

## **Design of elastic network properties of protein machines**

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We construct and investigate prototypes of artificial molecular machines based on complex (nonlinear) elastic network models. Our studies are inspired by real protein machines that control essential functions in the biological cell. Using evolutionary optimization algorithms we design elastic networks with spectral properties similar to those of real protein machines, that can serve as a molecular machine powered by ligand binding. With our model we can bridge the gap between time-consuming molecular dynamics simulations and rather simple phenomenological stochastic models. Different aspects such as energetics, regulatory mechanisms and dynamics of coupled machines can be studied.

## **The role of photo-degradation in the global carbon cycle**

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A long term litter decomposition experiment from sites around the world indicated that moisture and temperature predict decomposition rates well for most sites, but fail in semi-arid grasslands (Parton et al., 2007). Other studies have indicated that photo-degradation, particularly UV, may be important in litter decomposition in some arid and semi-arid environments (Pancotto et al., 2005; Austin and Vivanco, 2006; Gallo et al., 2006) With global change, photo-degradation may become more important as many areas are expected to become drier, and a thinner ozone layer may also increase UV-B-exposure. The chemical process of photo-degradation has also been studied in the lab, and the process has been described mathematically (Primo et al., 2007).

No simulation model includes the effect of photo-degradation. We have developed a simple linear equation for photo-degradation based on literature data. Parameters appear to be reasonably constant in different environments. We are presently estimating the importance of photo-degradation world-wide. The equation can easily be introduced into global models like JULES (Cox et al., 1999) and RothC (Jenkinson et al., 1987; Coleman and Jenkinson, 1999).

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# The effect of luminal calcium on the stability of coupled gating between ryanodine receptors

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**Aim:** Two or more ryanodine receptors (RyR) –  $\text{Ca}^{2+}$  channels reconstituted into a bilayer lipid membrane (BLM) can open and close either independently (single gating) or simultaneously (coupled gating). The coupled gating phenomenon has been suggested as an attractive candidate for a termination mechanism of  $\text{Ca}^{2+}$  release from the intracellular  $\text{Ca}^{2+}$  store, required for periodic contraction and relaxation of cardiac muscle.

**Methods:** Using the method of reconstitution of a channel into BLM, we investigated the potential effect of luminal  $\text{Ca}^{2+}$  on the stability of interaction between coupled RyR channels isolated from the rat heart. We introduced a new parameter - the coupling stability for each detected simultaneous opening and closing and further averaged values for experiments performed under identical conditions. **Results:** We found that the coupling stability during simultaneous opening of RyR channels was significantly lower in comparison to the simultaneous closing under the same experimental conditions. Furthermore, high concentration of luminal  $\text{Ca}^{2+}$  ( $53 \text{ mmol L}^{-1}$ ) as well as the absence of luminal  $\text{Ca}^{2+}$  noticeably destabilized functional coupling between coupled RyR channels during opening, in contrast to lower tested concentrations ( $8\text{--}20 \text{ mmol L}^{-1}$ ).

**Conclusions:** We provided experimental evidence that the strength of interaction between coupled RyR channels depends on the functional state of the channels. Furthermore, we showed, for the first time, the regulation role of luminal  $\text{Ca}^{2+}$  in the inter-RyR functional coupling in the heart.

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## The simplest chemical signal diodes

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Excitable chemical media can be used for acquiring and transforming information coded in excitation pulses. A series of pulses form a signal. One of the simplest chemical signal processing devices is a diode that transmits pulses in one direction and stops propagation in another one. We show that many types of media with broken symmetry can function as chemical signal diodes. For example a diode can be made with just two different non-excitable gaps. If the symmetry is broken at the level of input and output channels then even a single non-excitable gap can work as a diode. If the system is two- (or three-) dimensional then the gap is not needed and just the junction of two excitable areas can force unidirectional signal propagation. We study the range of parameters where the diode action appears using numerical simulations based on the Oregonator model. Results are qualitatively confirmed in experiments with Ru-catalyzed Belousov-Zhabotinsky reaction.

## **Synchronization in chains of oscillators**

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Using our previous results on synchronization / 1-3 / we propose couplings between oscillators on chains in order to synchronize. Numerical results will be shown on FitzHugh-Nagumo oscillators. Both unidirectional and bidirectional couplings are used.

1/I.Grosu,"Robust Synchronization" PRE 56 ,3709,1997

2/I.Grosu , IJBC 17,3519,2007

3/I.Grosu et al , PRL 100,234102 (2008)

## **Respiration Induces Metabolic Oscillations in Erythrocytes**

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Erythrocyte metabolism is influenced by the chemical properties of the blood. In this study we have extended a comprehensive model of erythrocyte metabolism by Mulquiney and Kuchel (1999) with a kinetic model of the transition between oxy- and deoxy-hemoglobin (Hb). The transition follows a model of the oxygen dissociation curve developed by Dash and Bassingthwaite (2004). The partial pressures of O<sub>2</sub> and CO<sub>2</sub> are forced to follow the physiological values of blood in order to study the system during arterial and venous phases. Calculations show that glycolytic lactate production is almost 50% higher in the venous phase. Apparent oscillations are also seen for the concentrations of 2,3-BPG and Hb and Mg<sup>2+</sup>-bound metabolites. However, most intermediary metabolites show almost no fluctuations. We show that the period of respiration does not allow the system to reach a steady state in either compartment. The dynamics can be explained by the change in steady state location caused by the forcing combined with excitation of widely separated fast and slow relaxation modes.

## **Central nervous tissue – an excitable medium**

### **The retinal spreading depression**

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According to its physicochemical properties neuronal tissue, including the central nervous system (CNS) and thus the human brain, is an excitable medium, which consequently exhibits among others self-organisation, pattern-formation and propagating waves. Furthermore, such systems can be controlled by weak external forces (and other external parameters). The spreading depression (SD), a propagating wave of excitation-depression is such an event, which is additionally linked to a variety of medically important situations, classical migraine being just one example. Especially in retinal tissue, a true part of the CNS, the SD can be observed very easily due to its big intrinsic optical signal (IOS) by the naked eye and by video imaging techniques.

We have investigated the retinal SD and its control by external physical and physicochemical parameters, as there are for example gravity, electromagnetic fields temperature, and the substitution of H<sub>2</sub>O by D<sub>2</sub>O. Beyond this, especially due to its medical relevance, the control of CNS excitability by pharmacological tools is of specific interest and we have studied this question in detail, using the retinal SD as an experimental tool to collect information about the control of CNS tissue excitability by a wide selection of

drugs. The presented poster will focus on the control of retinal SD waves by some excitatory drugs and on the effects of D<sub>2</sub>O on the parameters of propagating SD waves.

## **Manipulating scroll rings by electric current**

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Certain types of cardiac arrhythmias are caused by three-dimensional analogues of spiral waves of excitation. These objects are called scroll waves, and if the line connecting the spiral tips (the filament) forms a closed loop they are labelled scroll rings. The filaments are subject to instabilities, which cause the scroll ring to expand or contract intrinsically depending on the excitability of the medium.

In order to better understand how such scroll rings may be manipulated (in the context of any 3D excitable medium, e.g. cardiac or neuronal tissues), we have studied the dynamics of a scroll ring in a Belousov-Zhabotinsky reaction subject to a constant electric current. The scroll ring was found to reorient with respect to the direction of the applied external electric current. Two stationary orientations were identified and their orientational stability determined. At a stable stationary orientation in absence of an external current, the scroll rings contract intrinsically and eventually self-annihilate. For low values of the external electric current density, the scroll rings still contracted, while for higher current densities the scroll rings expanded. This current-dependent behaviour was used to manipulate the size and life-time of scroll rings.

C. Luengviriyaya, S. C. Müller, M. J. B. Hauser, Phys. Rev. E **2008**, 77, 015201(R)

C. Luengviriyaya, M. J. B. Hauser, Phys. Rev. E **2008**, 77, 056214

## **From Stationary Interacting Front Patterns to Turing Structures in the Thiourea-Iodate-Sulfite System**

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We want to report on the experimental observation of sustained traveling domains, standing lamellar patterns, and Turing structures in the thiourea-iodate-sulfite (TU-IS) oscillatory and bistable reaction. Though hundreds of oscillatory and bistable reactions are known since the late 90's, only two single phase reactions had previously produced standing patterns: the CIMA reaction which provided the first example of stationary Turing patterns, and the FIS reaction where patterns result from front interactions in a spatially bistable system. The TU-IS and FIS reactions bear some similarities. They are both acid autoactivated reactions on which thiourea or ferrocyanide exert a negative feedback. The TU-IS is the second system leading to Turing structures, and the first one to produce both Turing and stationary interacting front patterns. It offers a unique possibility to study the transition between these two types of patterning mode. This study opens the way for the observation of non trivial sustained stationary patterns in a growing diversity of reactions.

## Reaction-Diffusion Systems: Directed Self-organization

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The importance of self-organization phenomenon was realized by scientists in 1950-1960 in connection with chemical kinetics and biology. Furthermore, in spite of numerous differences between various types of self-organization, there are only a limited number of models describing these processes. One of them is the reaction-diffusion (RD) model, which generally is introduced as:

$$dx_i/dt = u_i([x_i], \lambda) + D_i \nabla^2 x_i,$$

where  $x_i$  are the physical variables,  $\lambda$  – phenomenological parameters,  $D_i$  – diffusion coefficients.

Since RD-processes in themselves can be utilized as main facilities for self-assembling systems creating [1], the first problem, which must be solved in this connection, is getting knowledge about RD processes controlling. Here as RD-model the Belousov-Zhabotinsky (BZ) reaction is chosen. It has been exploring during long time and therefore it represents a class of the well studied 1D and 2D RD-models.

As well known BZ-reaction forms spiral patterns. When we use external impulses (UV-light, etc.) for reaction controlling, spirals are substituted by another patterns. The pattern forming is strictly depends on the frequency and the amplitude of forcing impulses. In this connection the problem can be reduced to the modeling of coupling between two oscillators: BZ-reaction and external impulses. The most interesting effect of their coupling is resonance. As mechanism of BZ-reaction is very complex (it consists of 80 elemental reactions [2]), here we have used simpler mathematical models for coupling oscillation studying.

1. Bartosz A. Grzybowski et al. //Soft Matter, 2005. 1. 114-128.

2. L. Gyorgyi, T. Turanyi, R.J. Field //J. Phys. Chem. 1990. 94 (18) 7162-7170.

## Oscillations in the concentration of some non-redox metal ions induced by a pH oscillator

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In the chemical oscillators developed in laboratories redox processes are responsible for the oscillatory kinetics. This implies that elements possessing no multiple oxidation states were supposed to be unable to participate in periodical chemical reactions. Recently a design method has been suggested that made it possible to induce oscillations in the concentration of non-redox species. The method is based on coupling a redox oscillator to an acid-base type complexation or precipitation equilibrium in which the target ion is incorporated. So far the concentration of  $Al^{3+}$ ,  $Ca^{2+}$  and  $F^-$  ions was shown to undergo oscillations when their pH-dependent equilibrium reactions were connected to a pH-oscillator. In this lecture we demonstrate that the concentration of  $Zn^{2+}$ ,  $Cd^{2+}$  and  $Co^{2+}$  can also be forced to oscillate. In the  $BrO_3^- - SO_3^{2-} - Mn(II)$  pH oscillator the metal ions exist as free ions at low pHs but they are bound in sulfite-precipitate if the pH is high.

## **Effects of non-ionic polymers on the dynamics of the Belousov–Zhabotinsky reaction**

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The behaviour of the Belousov–Zhabotinsky (BZ) reaction has been perturbed by adding non-ionic polymers. It has been found that all the oscillatory parameters are influenced by the presence of the additives to an extent which depends on their concentration. Moreover, the effect of non-ionic polymers on the reaction dynamics also depends on the concentration of the other constituent of system such as the cerium catalyst or the bromate.

The observed effects have been attributed to both the reactions of the polymer backbone and those of alcoholic end-groups. As a comparison, the effect of some low molecular weight alcohols has also been studied. A kinetic scheme for the perturbation has been proposed in the framework of the MBM mechanism simulating the additives behaviour.

## **Inwardly propagating spiral waves in a biochemical system**

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Inwardly propagating spiral waves (anti spirals) are rarely observed in experiments with oscillatory or excitable dynamics, although theoretical analysis predicts their occurrence in such media close to the onset of oscillations. In a variant of the Belousov-Zhabotinski reaction, the BZ-AOT water in oil microemulsion it was shown that the concentration and size of water droplets act as a tuning factor leading to different types of patterns. We present results about pattern formation of glycolysis in a yeast extract and show that the protein concentration in the extract acts as a similar tuning factor, leading to the transition from normal spirals to antispirals.

Model systems describing the glycolytic pathway exist at different levels of complexity. Here, we consider several variants of the Goldbeter model, which appropriately account for the allosteric regulation of the phosphofructokinase by its substrate ATP and its product ADP. We investigate under which conditions inwardly propagating spiral waves emerge in these models and compare them with the experimental results.

## **Signal Transmission and Wave Propagation in Excitable Media Including Inhomogeneities**

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The diversity of patterns which can be found in extended excitable media range from single wave segments over target patterns to rotating spirals. They are of great interest in various fields like medicine, neurobiology or bio-chemistry. We want to study effects of inhomogeneities which can act as defects (e.g. in the inner heart medium) or excitable sites embedded in a passive surrounding (e.g. calcium channels in cells). The stability of moving excitation waves passing a non-excitable barrier as well as the signal transmission through purely diffusive media depends not only on the intrinsic dynamics but also on the geometry and configuration of the inhomogeneities.

Furthermore considering such complex extended systems as coupled single excitable elements affected by external signals and separated by inactive zones one obtains analytical results for the propagation failure or activation rates.

**Parameter calibration and validation of biological models by a  
multi-objective optimization technique:  
Application to the validation of a morphogenesis model  
for the establishment of the gradients of  
Bicoid and Caudal proteins in *Drosophila***

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We present two different models to analyze the distribution of Bicoid and Caudal proteins along the antero-posterior axis of the embryo of *Drosophila*. Bicoid protein represses caudal mRNA, and these proteins determine the anterior and the posterior poles of the embryo. In the first model, we assume that protein Bicoid is produced and then diffuses along the embryo.

In the second model, diffusion occurs at the level of mRNAs, and proteins stay localized near ribosomes, as observed experimentally. We apply a stochastic multi-objective optimization algorithm to calibrate the parameters of the models with the experimental data, and we compute the associated Pareto front.

**Functional role of an inhibitor: complete inhibition of CO and CO<sub>2</sub>  
evolution in the Briggs-Rauscher (BR) reaction by resorcinol,  
and search for the reactions producing CO and CO<sub>2</sub>**

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Recently we have discovered<sup>1</sup> that there is an intense CO and CO<sub>2</sub> evolution in the BR reaction. The gas evolution has both an oscillatory and a non-oscillatory component. According to our latest experiments<sup>2</sup> I<sub>2</sub>MA decarboxylates with a measurable rate. It was a logical hypothesis to assume that at least a part of the non-oscillatory CO<sub>2</sub> evolution is due to the decarboxylation of diiodomalonic acid (I<sub>2</sub>MA). We hoped that the non-oscillatory CO<sub>2</sub> evolution could be detected separately if we suppressed the oscillations, and measured I<sub>CO<sub>2</sub></sub> after that. Cervellati and coworkers reported that resorcinol is able to inhibit the oscillations in the BR reaction thus we applied that inhibitor. To our surprise during the inhibitory regime both CO and CO<sub>2</sub> evolution rates were practically zero (below the measurability level). Thus we can conclude that decarboxylation of I<sub>2</sub>MA is not a significant source of CO<sub>2</sub> in the BR reaction.

Then we assumed that reaction of inorganic free radicals with malonic (MA) and iodomalonic (IMA) acids are those reactions which are responsible for the CO and CO<sub>2</sub> production. To prove that hypothesis we generated inorganic radicals with Fenton's reagent and with analogous systems<sup>3</sup>. We found that these radicals can generate some CO<sub>2</sub> when they react with MA but a substantial amount of CO + CO<sub>2</sub> evolution can be observed when they react with IMA.

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## Oscillations in the Concentration of Fluoride Ions Induced by a pH oscillator

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Sustained oscillations in the concentration of free fluoride ions can be generated when the  $\text{BrO}_3^- - \text{SO}_3^{2-} - \text{Mn(II)}$  oscillator is coupled either to  $\text{Al}^{3+} - \text{F}^-$  complex formation or to the  $\text{Ca}^{2+} - \text{F}^-$  precipitation process in a flow reactor. By careful analysis of relevant equilibria and optimization of the reactant concentrations, one can obtain  $[\text{F}^-]$  oscillations of several orders of magnitude as measured with an anion selective electrode. In this poster the method, the experimental and the calculated oscillations will be shown.

## The influence of stochasticity on the dynamics of biochemical systems

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Biochemical systems show a transition from stochastic to quasi-deterministic behavior with increasing particle numbers. In the limit the deterministic solution and the stochastic solutions converge. We investigated this transition in different systems and different dynamical regimes, such as spiking or bursting oscillations. This is important for both the understanding of robustness in cellular systems and for decisions about which simulation method is appropriate. In our main test system, namely signal transduction via calcium, we observe that the transition occurs within a range of particle numbers which roughly corresponds to the number of receptors and channels in the cell, and depends heavily on the attractive properties of the phase space of the respective systems dynamics. Based on these preliminary results, we also found the same dependence was found in other test systems, such as buffered calcium oscillations, the peroxidase-oxidase reaction and MAP kinase cascades.

## Dynamic evolution of the hemin - hydrogen peroxide - sulfite reaction upon addition of a zwitterionic surfactant

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The peculiar feature of an aggregated system has been exploited in order to obtain a better insight into the complex mechanism of the pH oscillating hemin- hydrogen peroxide – sulfite reaction. In particular the effect of the zwitterionic surfactant tetradecyldimethylamine oxide ( $\text{C}_{14}\text{DMAO}$ ) on the dynamics of this reaction of has been investigated at 25.0 °C in a Continuous Stirred Tank Reactor (CSTR). The zwitterionic surfactant has been chosen because it is able to form micelles which undergo shape transitions depending on the experimental conditions used for the dynamical experiments, and the critical micellar concentration as well as the concentrations of the shape transition is pH sensitive.

It was found that the presence of the surfactant affects the oscillatory parameters to an extent which depends on its concentration. Explanations of the experimental results have been given on the basis of the peculiar capability of the surfactant assemblies to affect the reactivity by sequestering some key reacting species. In particular the observed effects have been interpreted in the light of the interaction between the hydrophobic hemin species and the zwitterionic surfactant. In order to elucidate the observed effects, a systematic study on the partition of the hemin between the aqueous and the micellar phase, by means of spectrophotometric measurements has been undertaken. The spectrophotometric data have been analyzed according to the pseudo-phase distribution model in order to determine the binding constants and the

locations of the hemin with respect to the surfactant aggregates. Moreover, the critical micellar concentration of the surfactant under the used experimental conditions as well as the effect of the observed pH change on this critical concentration of the surfactant, has been determined through surface tension measurements. The obtained results have been analyzed in order to propose a chemical reaction mechanism associated with the perturbation.

## **Patterns and oscillations in coupled populations in metapopulation networks**

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Interacting populations often create complicated spatiotemporal behavior, and understanding it is one of the basic problems in the dynamics of spatial systems. We study a two-species case by numerical simulations of a model of hosts and parasitoids. When the two species coexist, there are spatial patterns leading to noise-sustained oscillations different from limit cycles. We introduce a new measure for the patterns, and explain the oscillations as a consequence of a separation of two intrinsic timescales, and noise. We theoretically link the oscillations and the patterns together by letting the spreading rates depend on instantaneous population densities. The analysis has applications in realistic systems of metapopulation ecology as well as in surface science.

## **Density fingering of autocatalytic reactions in polyelectrolytes**

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We have studied the density fingering of an acid-catalyzed autocatalytic reaction in the presence of carboxylate containing polyelectrolyte. The decrease in viscosity as a result of the change in the ionic character of the polymer due to the pH-change during the reaction is the major driving force for the spatiotemporal pattern formation. The diffusion coefficients of the carboxylate containing species are determined by PFGSE-NMR. The front evolution is quantitatively characterized by dispersion curves.

## **“Catch me if you can” - Collective Motion due to escape and pursuit behavior**

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A common explanation for emergence of collective migration in a wide range of animals is that it serves as a protection mechanisms against predators. Recent studies by Simpson et. al. [Simpson et. al., PNAS, 103:4152-4156, 2006] and Bazazi et. al. [Bazazi et. al., Current Biology, 18:735-739, 2008] suggest that cannibalism can also be a driving mechanism for coordinated migration of swarming insects such as locusts and mormon crickets. Motivated by these novel results we introduce a simple model of Brownian particles interacting by pursuit and escape interactions. We show that these interactions lead to coordinated migration of groups and that experimentally accessible macroscopic observables depend strongly on the ratio of escape and pursuit interactions. We discuss the different impact of escape and pursuit behavior on the motion statistics and derive approximate solutions for the migration speed in dependence on model parameters. Furthermore our model shows the existence of an optimal random mobility (noise) level with respect to the migration speed for the nonlinear friction case, which is absent in the linear friction case.

# Dynamics of the Belousov-Zhabotinsky reaction in the presence of zwitterionic micellar aggregates

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Aggregated systems have been widely used in many different fields of chemical and material sciences. Peculiar proprieties arising from their supramolecular structures may be usefully exploited also in the study of non linear dynamic phenomena.

In this work the interaction between self-assembling aggregates of *N*-Tetradecyl-*N,N*-dimethylamine oxide (C<sub>14</sub>DMAO) and the Belousov-Zhabotinsky (BZ) chemical oscillator has been investigated in different experimental conditions by means of spectrophotometric measurements together with model calculation.

The appearance of an induction period with a threshold-like dependence upon the surfactant concentration, was detected at [C<sub>14</sub>DMAO] = 5.0 x 10<sup>-3</sup> mol dm<sup>-3</sup>. These new features were explained in terms of the segregation ability typical of the amphiphilic self-assembling systems. A comparison with an anionic micellar system (sodium dodecylsulfate) together with numerical simulations gave useful hints to understand and elucidate the interaction mechanism between the BZ reaction and the surfactant.

## Salt contaminated weak acid - weak base diodes

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The electrolyte diode studied here is made of a hydrogel cylinder connecting an aqueous acidic solution with an alkaline one, with an electric potential difference between the acidic and alkaline reservoirs. The current-voltage characteristic of a gel cylinder under such conditions resembles to that of a semiconductor diode [1-3].

A so called salt effect [4] occurs when a salt is added to the alkaline or the acidic reservoir and the current of the reverse biased diode increases in a nonlinear way. This effect was studied in strong acid - strong base diodes. Furthermore, recently the so called counter salt effect was discovered. In this case one side of the diode is contaminated with salt and salt is added to the opposite side too. It results that the 'larger' salt concentration decreases the current.

The salt effect and counter salt effect occur also in weak acid - weak base diodes according to our model calculations, however, there are differences too. This poster presents the model calculations about the salt contaminations in weak acid - weak base diodes.

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## Time-delayed feedback control of traveling waves

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We propose a mechanism to suppress spatio-temporal pattern formation in excitable media based on feedback control. As a generic model for excitable media the FitzHugh-Nagumo system with diffusion in

the first variable (activator) is investigated in a one dimensional domain. We show that by applying time-delayed feedback control in this system, the propagation of traveling pulses can be suppressed. The suppression can be explained by a shift of the propagation boundary in the parameter space of the model. This boundary is a bifurcation of codimension one separating the parameter regime of pulse propagation from the regime where a local disturbance dies out. The optimization of this feedback and its characteristic time scales are discussed for different control schemes and ranges of control parameters. Moreover, we discuss a mechanism for the emergence of spreading depolarization, i.e., reaction-diffusion waves occurring under neurological conditions such as migraine and stroke, by impaired neurovascular coupling that provides a natural time-delayed feedback signal.

## **Synchronized dynamics in diffusion-coupled biochemical oscillators**

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Some biochemical oscillators, such as calcium system, produce irregular spikes due to random opening of intracellular receptors. In the simplest case, their dynamics can be modelled as an excitable system subject to small random fluctuations. Using a model of calcium kinetics and other simple biochemical models, we examine dynamics of a chain of diffusion-coupled excitable units under periodic and/or stochastic fluctuations with focus on their synchronous behavior, which is taken as a measure of coordinated cellular action.

## **New bubble free BZ reaction in lipidic biomimetic matrices**

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This work reports on the chemical waves and patterns formed by the Belousov-Zhabotinsky (BZ) chemical oscillator when phospholipid membranes in water are used as matrix. A drawback of the usual recipe for the BZ reaction-diffusion system (Ferroin as catalyst, Malonic Acid, MA as organic substrate) is the production of carbon dioxide, which results in the formation of bubbles and, consequently, in the onset of convection phenomena. Many attempts have been made to develop gas-free versions of the BZ reaction. For instance, in the method developed by Kurin-Csorgei and coworkers [J.Phys.Chem. 1996. Vol.100, 5393-5397], 1,4-cyclohexanedione (CHD) is used as an organic substrate in the place of Malonic acid. Here we describe the spatio-temporal patterns obtained when the BZ reaction performed with CHD as the substrate, is carried out in the water domains of 1,2-dipalmitoyl-sn-glycero-3-phosphocholine (DPPC) lamellar phases. We characterized patterns and dynamics, wave typologies and diffusion relations. We also compared the BZ-CHD/DPPC system results with those obtained in the absence of lipids and with the BZ-MA/DPPC system. Special attention was finally placed on the intriguing role of the DPPC/water as a prototype biomimetic matrix.

## **Intracellular Signaling Gradients and Surface Diffusion Problems in a Spherical Cell**

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In the first part, we consider intracellular signaling gradients as they arise from a multiple of compartments by the action of a localized enzyme (kinase or GEF) in conjunction with an antagonistic cytosolic enzyme

(phosphatase of GAP). Using asymptotic methods we derive explicit expressions for the concentration profile of activated signalling molecules for an arbitrary configuration of compartments. In the second part, we consider the diffusion of a molecule on the surface of a spherical cell in the presence of an arbitrary number of traps. Here, we derive expressions for the (average) mean first passage time distribution.

## ***n*-dimensional ratio-dependent predator-prey systems with memory**

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Ratio-dependent predator-prey systems with delay are investigated. Conditions are given when delay cannot cause instability in higher dimension. An example is also shown when delay does cause instability.

Kiss, K., Kovács, S.: Qualitative behaviour of *n*-dimensional ratio-dependent predator-prey systems, *Appl. Math. Comput.* **199** (2) (2008), 535–546. doi: 10.1016/j.amc.2007.10.019

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## **Sensitivity analysis of a generic cell-cycle model**

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The generic cell cycle model of Csikász-Nagy et al [1] is a biochemical kinetic model that shows how the controlling protein concentrations change during a proliferation cycle. The model describes the cell cycle of several organisms in such a way that the system of ODEs is identical, but the values of parameters are different when the model is used for a different organism.

The model was investigated at parameter sets referring to budding yeast, fission yeast and mammalian cells. Time dependence of local sensitivity coefficients was calculated for all variables and parameters of the models. The period times of these models depend on the parameter values, therefore the sensitivity functions were blowing up (increasing continuously).

Since the amplitudes of the raw sensitivity functions tend to infinity according to a linear function, we used the methods of Larter [2], and Zak et al. [3] based on singular value decomposition to eliminate the secular term. This way the raw sensitivity functions were converted to periodic sensitivity functions and also the period sensitivities were obtained.

The periodic sensitivity functions were investigated further. For the budding yeast and the mammalian cell models, all these local sensitivity coefficient–time functions had similar shape, which means that these functions exhibited global similarity. For the fission yeast cell model basic shapes denoted A1, A2, B1 and B2 could be identified using a clustering method.

Similarity of the sensitivity functions and identification of excitable periods have been investigated [4, 5] using the Chen et al. model [6] for the cell cycle of budding yeast. One of the novelties of the present study is that the same model exhibited different similarity features in different domains of parameters.

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## Monte Carlo analysis of an enzyme kinetic network

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The cell cycle is the sequence of events by which a growing cell replicates all of its components and divides them into two sister cells. Csikász-Nagy et al. [1] have created a generic cell cycle model that is able to simulate several types of living cells in such a way that for each cell type the differential-algebraic system of equations are identical, but the values of the parameters are different. This common system of differential-algebraic equations contains 14 variables and 86 parameters. In our studies, parameter sets related to budding yeast, fission yeast and mammal cells were investigated. Since measured concentration–time curves are not available for these cells, a parameter set was considered successful, if the corresponding model simulated a proliferating cell. Otherwise, the modelled cell was considered dead. The requirement for a living cell was to produce at least one cell division in the first 500 minutes and in the last 280 minutes, during the 3000 minutes simulation time.

First, the parameters were changed one-at-a-time, while all the other parameters were kept constant at their nominal values. Increasing or decreasing a parameter by four orders of magnitude, the limits were explored where the cell remained still alive. The qualitative results for most parameters were similar for each cell type. This shows that the role of the parameters were basically conserved during the evolution. However, there were 13 parameters with different behaviour for the different types of cells.

To investigate parameter interaction, Monte Carlo analyses of the three cell type models were carried out. For each model, 100000 parameter sets were generated using Latin hypercube sampling assuming log-uniform distribution. In order to explore if a change of a parameter value can be compensated by a systematic change of another parameter to keep the cell alive, correlation of these parameter values was investigated.

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## The uncatalyzed bromate-aniline oscillator: Classical model system or a complex reaction with unexpected mechanism?

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The uncatalyzed bromate oscillator (UBO) with aniline in aqueous sulfuric acid exhibiting sequential oscillations has been studied. Nonlinear behavior of the system was monitored using potentiometry with Pt and Ag/AgBr electrodes and intermediates and products of the reaction were analyzed by means of the GC/MS technique during various stages of the reaction. The results show that the initial reactant aniline is not itself directly involved in the observed oscillatory dynamics as well as its brominated derivatives which rather suppress oscillations upon addition to the system. GC/MS analyses have revealed that (brominated) benzoquinone, though present in a significant quantity, is not a main product of the reaction as it was assumed so far, but intermediates resulting from aniline conjugation have been detected as dominant GC signals. Probably oxidation of these species leads to (biologically interesting) N-phenyl-2,3,4,5-

tetrabromopyrrole which has been clearly identified among reaction products. Mechanisms of the main products formation with respect to the observed oscillatory dynamics are discussed.

## **Stochastic description of the quorum sensing regulatory network in *Vibrio fischeri***

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Bacteria like the *Vibrio fischeri* are able to sense their own cell density by means of a gene regulatory mechanism combined with chemical communication. The main regulatory pathway includes an autoinducer that diffuses out of the cell and plays the role of the chemical signal. Above a threshold value of concentration for the autoinducer in the medium, the regulatory network activates the production of the luminescent molecule Luciferase. The bacteria can monitor the cell density through the autoinducer concentration and alter their behavior. This process, called quorum sensing (QS), is achieved through an appropriate gene network architecture including two main regulatory proteins, LuxI and LuxR.

We introduce a modeling approach for the QS regulatory network, including a deterministic and a stochastic approach of the N-cells system. The dynamics are modelled by a system of chemical kinetic equations and solutions are simulated with the Gillespie algorithm. The distribution of the steady states is calculated and the influence of parameters in the precision of the QS process is analyzed.

## **Power-law correlations and 1/f noise in the resting conductance of rat ventricular myocytes**

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Timing of the heartbeat exhibits fractal fluctuations over a wide range of time scales. Its origin is not well understood at the level of individual cardiomyocytes. Here we analyse the fractal dynamics of the resting sodium conductance in isolated ventricular myocytes.

Resting membrane currents of isolated rat ventricular myocytes (Wistar, males 200 - 250 g) were recorded in the whole-cell patch clamp configuration at a holding potential of -70 mV. Digitised current records were analysed using power spectral analysis and detrended fluctuation analysis. The resting current of myocytes exhibited fractal fluctuations typically at time scales longer than 30 ms. The power-law exponent in myocytes with a high resting potential (RP =  $-71.3 \pm 1$  mV) was close to 1, similar to the power-law exponent reported for the healthy human heartbeat, while spontaneously depolarised myocytes (RP =  $-18.3 \pm 1.7$  mV) exhibited a significantly higher power-law exponent ( $1.24 \pm 0.025$ ), similar to that of heartbeat fluctuations after myocardial infarction. Substitution of  $\text{Na}^+$  with the impermeant NMDG<sup>+</sup> or addition of  $\text{Gd}^{3+}$ , a non-specific blocker of various cation channels, decreased the amplitude of 1/f noise in both groups of myocytes. These interventions had no effect on the power-law exponent in well-polarized myocytes, while in spontaneously depolarised myocytes they reduced the power law exponent to 1. The predominant source of the resting membrane current noise was attributed to sodium influx mediated by a non-selective cation background conductance.

We suggest that fractal fluctuations of the resting sodium conductance may contribute to fractal dynamics of the heartbeat by modifying the threshold for triggering action potentials in individual myocytes.

# Dynamics of signal transduction in olfactory sensory cilia

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Olfactory sensory neurons detect odorant molecules inhaled into the nasal cavity, and constitute the first stage of the sense of smell. The transduction of the initial chemical signal (type and concentration of the odorants) into electrical signal (depolarization of the cell membrane) occurs in the dendritic cilia – long and thin cylindrical structures embedded in the nasal mucosa. We have analyzed the dynamics of this signal transduction process, concentrating in particular on the role of a negative feedback loop in which the cyclic-nucleotide-gated (CNG) calcium channel is inhibited by calcium-loaded calmodulin.

In a detailed deterministic model [1], we analyzed the coupled dynamics of intra-ciliar calcium, CNG channels, and calmodulin, and characterized the conditions under which the system undergoes a Hopf bifurcation. No autocatalysis (such as calcium-induced calcium release) is required for oscillations in this system. The model is in quantitative agreement with available recordings from vertebrate olfactory sensory neurons, both with respect to oscillations and to fast adaptation.

To analyze the regime of very low stimulus intensity, we have developed a reduced stochastic model [2,3]. The CNG channels are described as two-state point sources with transition rates dependent on the local calcium concentration. We obtain explicit analytical results to first order in feedback strength, and numerical results for the case of strong feedback. We show that the coefficient of variation for the steady-state calcium level can either increase or decrease, depending on the feedback strength and the calcium extrusion rate [2]. We analyze the combined effect of diffusion of calcium and local negative feedback [3].

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