Tetsushi Watanabe, Yoshimasa Komatsuzaki, Katsunori Tanaka, Minoru Saito (Department of Correlative Study in Physics and Chemisty, Graduate School of Integrated Basic Sciences, Nihon University)

Rhythmic patterns of electrical activity are a ubiquitous feature of nervous systems. The modulation of oscillatory activity plays an essential role in the processing of sensory information. We here examined the odor responses of oscillatory activity in the olfactory center (procerebrum; PC) of the land slug *Limax* by extracellular recording. The PC was isolated together with the tentacle and the carrot or cucumber odor was applied only to the tentacle. The local field potential (LFP) of the PC was recorded through a suction electrode filled with the saline and sampled with 1 kHz. Prior to the odor stimulus, the LFP showed an oscillation of about 0.5-1 Hz. The continuous exposure of each odor to the tentacle slightly increased the frequency, while the marked difference was not found between each odor. Then we tried to reconstruct the attractor from the time series of each LFP. The result showed the different characters in the attractors. We further examined the odor responses of the slugs subjected to aversive training. In the training, the slugs were exposed to one of the odors as conditioned stimulus (CS), and then quinidine sulfate solution was immediately applied as an unconditioned stimulus (UCS) to the lip of the slugs. In these slugs, the bursting oscillation of LFP was induced by the CS odor after a few minutes from the exposure. The reconstructed attractor showed the onset of the bursting oscillation. The onset was also obtained by Wavelet analysis.

2P-312 2つのリン酸化サイトを区別したモデルによるKaiCの概日リズムのシミュレーション

Simulation of circadian rhythm of KaiC with a model considering dual phosphorylation sites

Tetsuro E Nagai, Tomoki P. Terada, Masaki Sasai (Department of Computational Science and Engineering, Nagoya University)

In the cyanobacterium Synechococcus elongatus PCC 7942, KaiA, KaiB, and KaiC are essential proteins for the generation of a circadian rhythm. The robust circadian oscillation of KaiC phosphorylation can be reconstituted by incubating three Kai proteins with ATP in vitro (Nakajima et al., 2005). Recently, it was shown that KaiC has two autophosphorylation sites, Ser431 and Thr432, and their sequential phosphorylation/dephosphorylation serve as the basis for circadian rhythm generation (Nishiwaki et al., 2007). Moreover, there is a proportional relation between the rate of ATP hydrolysis and the frequency of the KaiC phosphorylation cycle (Terauchi et al., 2007). Considering that the ATP hydrolysis is a basic reaction to determine the time constant of phosphorylation cycle, we build a model treating dual phosphorylation sites which should be related to the ATPase activity. The model reproduces the experimental result that the KaiC phosphorylation cycle is generated by sequential phosphorylation/dephosphorylation at two autophosphorylation sites. It was also observed that KaiC monomers are exchanged between KaiC hexamers in a circadian fashion (Kageyama et al., 2006), and that after mixing the dephosphorylation-phase KaiC and the phosphorylation-phase one, all the KaiC undergoes dephosphorylation (Ito et al., 2007). Our model explains the mechanism of this synchronization of KaiC phosphorylation cycle through shuffling reactions and shows the fundamental importance of shuffling reactions for maintaining stable cycles.

2P-313 単一興奮性細胞の遅い揺らぎのダイナミクス

Dynamics of slow fluctuations of single excitable cells

Takahiro Harada (1), Tomomi Yokogawa (1), Tomoshige Miyaguchi (2), Hiroshi Kori (3).(1: Dept Human and Artificial Intelligent Systems, Univ of Fukui; 2: Dept Applied Physics, Graduate School of Engineering, Osaka City Univ; 3: Advanced Interdisciplinary Research Division, Ochadai Academic Production, Ochanomizu Univ)

In various kinds of cultured cells, it has been reported that the membrane potential exhibits fluctuations with long-term correlations, although the underlying mechanism remains to be elucidated. A cardiac muscle cell culture serves as an excellent experimental system to investigate this phenomenon because timings of excitations can be determined over an extended time period in a non-invasive manner through visualization of contractions, although the properties of beat-timing fluctuations of cardiac muscle cells at the single-cell level remains to be fully clarified.In this presentation, we report on our detailed investigation of spontaneous contractions of cultured rat cardiac muscle cells at the single-cell level. It was found that single cells exhibit several typical temporal patterns of contractions and spontaneous transitions among them. Detrended fluctuation analysis on the time series of interbeat intervals revealed the presence of $1/f$ noise at sufficiently large timescales. Furthermore, multifractality was also found in the time series of interbeat intervals. These experimental trends were successfully explained using a simple mathematical model, incorporating correlated noise into ionic currents.From these findings, it was established that singular fluctuations accompanying $1/f$ noise and multifractality are intrinsic properties of single cardiac muscle cells.

2P-314 ＳＳＡとＲＲＥの相互作用に基づく同的階層モデル

Dynamically hierarchical model based on the interaction of SSA and RRE

Yukio-PegioGunji(1)(1:Dept Earth & Planetary Sciences, Faculty of Science, Kobe Univesity)

Although macroscopic and microscopic perspectives are expected to be consistent with each other, there can be discrepancy between them. Lotka reaction simulated by stochastic simulation algorithm (SSA based on Gillespie algorithm) reveals that an initial state located at an equilibrium point can move and is attracted into an oscillatory orbit, while an equilibrium point simulated by a reaction rate equation (RRE) never moves. The effect of perturbation can take different role in micro and macroscopic perspectives. Although the discrepancy sounds like negative thing, it can mediate microscopic phenomena with macroscopic ones with huge flexibility. The microscopic reaction probability can be changed dependent on the macroscopic state so as to compensate for the effect of perturbation. There is no such conquering weapon as the necessity of conquering. Here we propose a model for a dynamically hierarchical system in which there could be negotiation which can compensate for the discrepancy between micro- and macroscopic perspectives. Reaction rate equation is simulated with the time interval supplied from the microscopic perspective, and stochastic simulation is carried on with the reaction probability supplied from the macroscopic level. It implements perturbation that can compensate for the discrepancy between two levels, dependent on the time interval and/or the reaction probability. Dynamic negotiation can reveal implicit internal structure of a component by which it can refer to the macroscopic level.

2P-315 化学振動反応装置間で発生する振動現象の測定

Observation of oscillation phenomena between reactors for oscillating chemical reaction

Yuki Sugihara(1) and Satoka Aoyagi(1)(1: Faculty of Life and Environmental Science, Shimane University)

Interaction between oscillation phenomena such as synchronization, is one of the most interesting features of non-linear science. In order to apply oscillation phenomena to artificial devices, the interaction should be investigated and be controlled. Influences of reactor types or reactor numbers on interaction between reactors of Briggs-Rauscher (BR) reaction, one of the famous oscillating chemical reactions, were evaluated.In terms of the reactor types, semi-batch reactors and continuous stirred tank reactors (CSTR) were compared. Two or three reactors were connected with silicon tubes, and a solution in a reactor was flowed into the other reactor using a pump.As a result, oscillation of the cycle time of BR reaction in the two interacted semi-batch reactors was observed. This oscillation was not observed when three semi-batch reactors were employed. In case of three semi-batch reactors were applied, rhythms of the reactors were finally synchronized. Moreover it was not observed when CSTRs for BR reaction were employed independent of the number of the reactors.In conclusion, oscillation phenomena between oscillating chemical reactors occurs depending on a condition. In other words, when two of semi-batch reactors of BR reaction are interacted their rhythms of BR reaction are also oscillated though three of semi-batch reactors are finally synchronized.

2P-316 Controls of energy flows in biochemical reaction systems

Controls of energy flows in biochemical reaction systems

Akinori Awazu (Department of Mathematical and Life Sciences, Hiroshima Univ.)

Energetic properties of the models of ideal reaction systems inspired by several biochemical reaction systems are studied. We focus on the energyconversion and the dissipation in the following reaction systems withdifferent characteristic scales, the molecular machines and the catalyticreaction networks.

First, simple thoughtful models of micro autonomous energy transducers,pumps and motors, working under the large fluctuations are considered.We construct some ideal energy transducers working like ion pumps,rotating motors or linear motor in living cells by using the followingobjects, ``rotating head'', ``gates'' and ``stopper'' which interactwith ligands. Through the considerations of such ideal machines, we tryto uncover the universality and the individuality of the design and motions of several molecular machines in living cells.

Second, the relaxation to equilibrium in ideal catalytic reactionnetworks is considered in order to investigate the energy flowsin biochemical reaction networks in living systems. We show that, ingeneral, the catalytic random reaction networks exhibit much slowerrelaxation with the stepwise energy dissipation. Through the considerations of such dynamics, we try to discuss thepossible mechanisms of the controls of the energy flows by biochemical reaction processes.

2P-317 生物時計試験管内再構成系の同期と特異点

Synchronization and singularity behavior of a biological clock in vitro

Masaru Kojima(1), Hiroshi Ito(1), Maho Miyazaki(1) and Takao Kondo(1)(2)(1: Division of Biological Sciences, Graduate School of Sciences., Nagoya University; 2: CREST, Japan Science and Technology Corporation(JST))

Biological clock has been considered as limit cycle oscillator. In general, limit cycle oscillator has a phase singularity, the point at which phase is ambiguous and near which phase takes on all values. For example, it was reported that the specific stimulus at the specific time induces arrest of the circadian clock in mammalians cell (Ukai *et al.* 2007) and chlamydomonas (Johnson and Kondo 1992). Ghosh *et al.* (1971) mixed two yeast cells suspensions with different phases of metabolic oscillation and observed the phase of the mixture. They realized the mixture composed of the specific phase suspension had an unsettled phase.

Recently, our group found that the cyanobacterial circadian clock could be reconstituted *in vitro* only by mixing the three clock proteins, KaiA, KaiB, KaiC, with ATP. Namely, the ratio of phosphorylated KaiC woscillates every 24hr in the mixture (Nakajima *et al.* 2005). To reveal this reconstituted system act as singularity behavior, we explored a singularity point in this assay. We prepared different phase circadian clocks (every 2 hr) and mixed them all combination, and

ポスター2日目