Kobayashi's LAB.

[Mathematical Approach for Biology]

Laboratory for Quantitative Biology
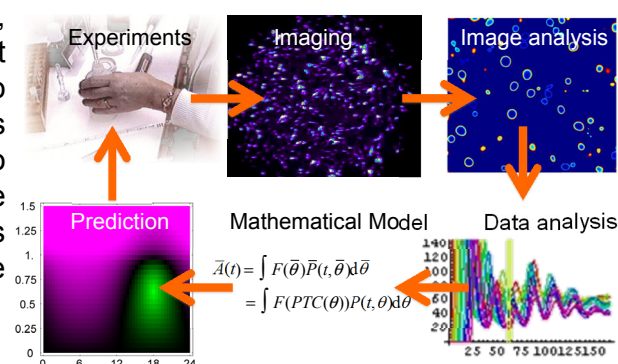
http://research.crmind.net

Systems biology, Quantitative biology, Theoretical Biology

Department of Electrical Engineering and Information Systems (EEIS)
Department of Mathematical informatics

Frontier of Biology as an Interdisciplinary Science

Cellular phenomena such as development, immunity, and cancer are intrinsically dynamics. Recent development of bio-imaging technology enables us to directly and quantitatively observe these dynamics. This innovation in turn drives the frontier of biology to become an interdisciplinary field by incorporating the knowledge and technologies of other fields such as engineering, informatics, and mathematics where quantitative data and analysis are commonly used.

Experiments → Imaging → Image analysis

Prediction   Mathematical Model   Data analysis

$$\bar{A}(t) = \int F(\bar{\theta})\bar{P}(t,\bar{\theta})\mathrm{d}\bar{\theta}$$
$$= \int F(PTC(\theta))P(t,\theta)\mathrm{d}\theta$$

Information Technology for Biology

Information technology such as image and data analysis is indispensable to exploit the potential information that bio-imaging data have. We have developed methods for 4D tracking of mouse embryogenesis (Fig.1), detection of epidermal cells (Fig. 2), and prediction of peptide folding and its determinants (Fig. 3). By using these methods, we have revealed that desynchronization of circadian cells underlies singularity phenomena in which stop of circadian oscillation is induced by unusual midnight light.

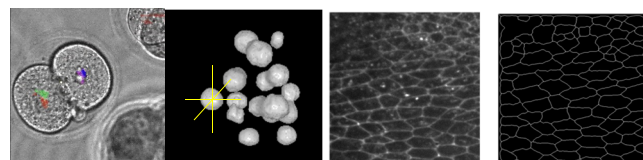Ukai , Kobayashi, et al., (2007), Nat. Cell Biol.

Fig.1 Image analysis of embryogenesis

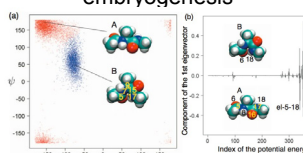Fig. 2 Image analysis of epidermal cells

Fig. 3 Potential energy PCA analysis of peptide folding
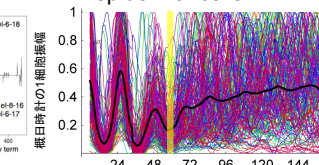
Fig. 4 Desynchronization of cells induced by mid-night light

Theory for robust operation of a cell with noisy components

Mathematical modeling is also crucial to understand design principles of dynamic biological systems. For example, bio-imaging revealed that cellular systems can operate robustly even with substantial noise in their components. However, its mechanism still remains unknown. By combining statistical theory with that for stochastic chemical reaction, we have theoretically clarified that a very simple intracellular reaction can conduct surprising information-processing to extract relevant information from very noisy signal. This theory may also be employed to design noise-immune engineering systems.

Kobayashi,, Phys. Rev. Lett., 2010, 2011

(A) State of environment x_t=off r_{on} x_t=on
r_{off}
(C) λ_{off} λ_{on}
Receptor activities
$S(t)$
(E) Intracellular kinetics
$1-P(t)$ $F(P,S)$
$G(P)$ $P(t)$

(B) State of environment $\lambda(x(t))$
(D) $N(t)$ Receptor activities
(F) Intracellular kinetics $P(t)$