【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Mathematical and Physical Sciences)

Title of Project : Macroscopic Theory for Robustness and Plasticity in Cells

Kunihiko Kaneko
(The University of Tokyo, Graduate School of Arts and Sciences, Professor)

Research Project Number : 15H05746 Researcher Number : 30177513
Research Area : Physical and Mathematical Sciences
Keyword : Biophysics, Evolution, Fluctuation, Single-cell Measurement

【Purpose and Background of the Research】

Biological systems are robust to noise and changes in external environment, while they are plastic to adapt to such changes. Characterization of plasticity, robustness, and evolvability in terms of dynamical systems and statistical physics, then, is essential. Previously we studied proportionality among evolution speed, phenotypic plasticity, and isogenic phenotypic fluctuation, and uncovered possible roles of noise to adaptation and robustness in evolution. Experimentally, quantitative data on expression levels of thousands of genes, cell-to-cell fluctuation in protein abundances, and changes in genomic sequence through evolution are now available. From these data, we have proposed a macroscopic theory of fluctuation and responses in expressions across genes, by assuming that cells undergo steady growth. Following these studies, we intend to establish a macroscopic theory for robustness and plasticity through the course of adaptation and evolution..

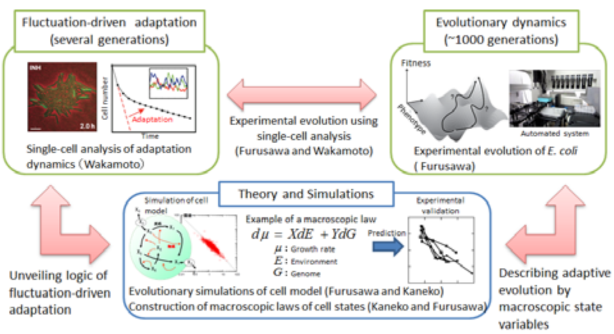

Fig.1

【Research Methods】

(1)Through long-term single-cell measurement, we establish statistical laws on fluctuations in cell-growth speed, and gene expression levels, and uncover a mechanism for adaptation by noise. (2) Through laboratory evolution of bacteria under a variety of stresses, we mad high throughput measurement of changes in genomic sequences and phenotypic changes, from which we extract a few macroscopic quantities to characterize adaptive evolution. (3) Through single-cell measurement over generations, we measure phenotypic changes at an evolutionary time scale. (4) By carrying out extensive numerical evolution experiments of toy cell models and combining their results with those from the above laboratory experiments, we establish a macroscopic state theory for adaptation and evolution.

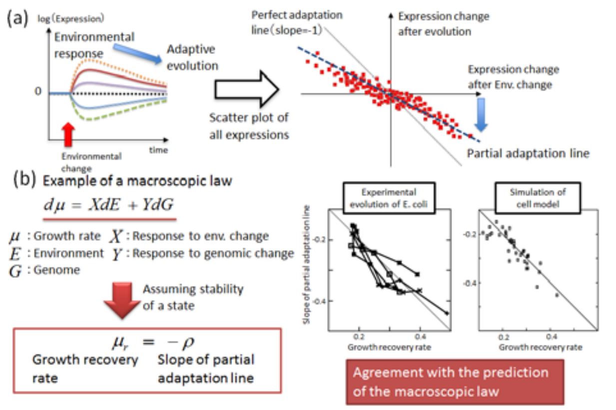

Fig.2

【Expected Research Achievements and Scientific Significance】

Based on the results, we revisit Waddington's canalization and genetic assimilation, and discuss how consistency between evolutionary and developmental scales constrains developmental process and leads to universal laws on phenotypic fluctuations.

【Publications Relevant to the Project】

K. Kaneko, Life: An Introduction to Complex Systems Biology, Springer, 2006
K.Kaneko,C.Furusawa,T.Yomo,Phys.Rev.X(2015) 5, 011014
S.Suzuki, T.Horinouchi, C. Furusawa, Nat. Comm (2014)5, 5792
Y.Wakamoto, et al., (2013) Science. 339(6115): 91-95.

【Term of Project】 FY2015-2019

【Budget Allocation】 140,400 Thousand Yen

【Homepage Address and Other Contact Information】

http://chaos.c.u-tokyo.ac.jp
kaneko@complex.c.u-tokyo.ac.jp