# Mathematical Models of the Feedback between Population Dynamics and Biological or Cultural Evolution

**Shota Shibasaki**[1]

[1]*Faculty of Culture and Information Science, Doshisha University*

**ABSTRACT**

Temporal changes in populations are a central topic in biology. Ecologists have studied how the number of individuals within a population changes over time (i.e., population dynamics), while evolutionary biologists have examined how population-level characteristics, such as the mean and variance of trait values, evolve (i.e., evolutionary dynamics). Traditionally, evolutionary dynamics were considered much slower than population dynamics because evolution occurs through the accumulation of mutations and natural selection over many generations. However, over the past decade, both empirical and theoretical studies have shown that evolutionary dynamics can happen much faster than previously assumed; they can influence population dynamics and vice versa. Such rapid evolution, for example, allows a population to survive under environmental stresses that would otherwise lead to extinction. Moreover, recent research suggests that evolution occurs not only through genetic changes (biological evolution) but also through learning from others (cultural evolution). In this talk, I will first present a mathematical model and experimental results where a population can avoid extinction under environmental fluctuations by changing the mean and variance of trait values. I will then introduce a mathematical model of cultural evolution to explore the mechanisms for maintaining trait diversity within populations, which may influence population resilience and adaptability. Finally, I will outline an ongoing research direction: investigating how cultural evolution might influence population dynamics, and how its effects may differ from biological evolution.

**Keywords:** biological evolution; cultural evolution; mathematical model; population dynamics



Back to Sessions List

# Structure-Plasticity Interactions Shape Self-Organized Criticality in Neural Networks

**Yoshiki A. Sugimoto[1]**, Masato S. Abe[2,3,4]

[1]*Graduate school of Culture and Information Science, Doshisha University*

[2]*Faculty of Culture and Information Science, Doshisha University, Kyoto, Japan*

[3]*Center for Advanced Intelligence Project, RIKEN, Tokyo, Japan*

[4]*CBS-TOYOTA Collaboration Center, Saitama, Japan*

## ABSTRACT

Multiple observations suggest that neural activity operates near the boundary between order and disorder—the vicinity of criticality—and this regime has been linked to broad dynamic range, efficient information transmission, and a balance between stability and flexibility. With self-organized criticality (SOC) in mind—namely, a feedback system that autonomously adjusts the system toward the critical regime through internal adaptive processes (e.g., synaptic plasticity) without relying on fine-tuned external parameters—this presentation adopts a framework that examines critical phenomena from two perspectives: (A) neuronal avalanches, in which activity-size distributions follow a power law, and (B) the edge of chaos, referring to flexible operating states near the boundary between chaotic and non-chaotic dynamics. From these viewpoints, we investigate how the interaction between network structure and synaptic plasticity realizes and sustains critical operation. Using compact spiking-network models that combine canonical topologies—small-world, scale-free, and modular—with self-tuning plasticity, we show how structural features and plasticity timescales expand or narrow the self-organized critical operating range in the vicinity of criticality.

**Keywords:** Brain criticality; Neuronal avalanches; Edge of chaos; Self-organized criticality (SOC).

# Explaining Parasite Diversity and Host Diversity in Nature

**Wei-chung Liu**

*Institute of Statistical Science, Academia Sinica, Taiwan*

**ABSTRACT**

Parasites are ubiquitous in nature and they constitute a substantial amount of biomass in an ecosystem. Previous studies have shown parasitism is not a random process and there is a great heterogeneity in parasite diversity among host species. Furthermore, parasitism tends to occur in topologically important positions in an ecological network. To date, the mechanism explaining such phenomena remains largely elusive. To this end, in this study, we construct a simple simulation model to explain the observed patterns of parasitism in nature. Our model takes an ecological network, or a food web, as given, then it allows parasite species to randomly infect host species as initial seeds; then in a probabilistic manner, parasite species are transmitted via the predator-prey links throughout the food web. We then investigate whether the resulting patterns of parasitism, specifically the distributions of parasite diversity and host diversity, as well as the topological nature of those infected host species, are similar to their empirical counterparts. We also construct a random parasitism model for comparison purpose, and investigate the extent to which parasite transmission via predator-prey links can account for the observed patterns of parasitism in nature.

**Keywords:** host, parasite, diversity, transmission, model



Back to Sessions List

# Mapping Citation Tendencies among Broad Subject Groups: Closed Fields, Asymmetric Exchange, Unexpected Ties and Structural Disconnection

Wei-Chu Chiang[1], **Frederick Kin Hing Phoa[1*]**, Hiroka Hamada[2]

[1]*Institute of Statistical Science, Academia Sinica, Taiwan*

[2]*Institute of Statistical Mathematics, Japan*

**ABSTRACT**

This study maps the interaction structure among broad knowledge fields using citation data from the Web of Science. Building on a previously constructed Pointwise Mutual Information (PMI) matrix that captures citation probabilities among 3120 subject types, we propose an aggregation method to approximate citation tendencies at the broader subject-group level - applicable when raw citation frequencies are unavailable. The resulting matrix offers a condensed view focused on interactions among "pure" subject groups. Our analysis reveals a clear contrast between "closed-fields" (e.g., the humanities) and "open-fields" (e.g., biology-related fields), with notable exceptions such as chemistry and medicine. Citation tendencies are generally reciprocal, though several prominent asymmetric pairs indicate imbalanced flows of knowledge. We also identify a set of unexpectedly strong cross-group citation ties, often rooted in interdisciplinary research niches. In contrast, several subject group pairs exhibit unusually weak citation links, likely reflecting disciplinary specialization rather than unrealized opportunities for integration. We argue that the citation tendency matrix at the subject-group level serves as a valuable foundation for studying interdisciplinarity. It provides empirical insights into the structure of cross-field knowledge exchange and could be further applied to research metrics design or other practical applications.

**Keywords:** Web of Science; Pointwise Mutual Information (PMI); Interdisciplinarity; Citation Tendency; Knowledge Exchange