# Evolutionary Game Theory and Applications

**Course number:** QSS 30.04

**Course time:** **2016 Fall 10A**

**Instructor:** Feng Fu

**ORC Description:** Pioneered by John Maynard Smith and others, evolutionary game theory has become an important approach to studying a wide range of biological and social problems, such as microbial interactions and animal behavior. In evolutionary game dynamics, the fitness of individuals depends on the relative abundance of all individual types in the population, and higher-fitness individual types tend to increase in abundance. The course introduces basic concepts in evolutionary game theory, including evolutionarily stable strategies, replicator dynamics, finite populations, and games on networks, along with applications to social evolution, particularly to understanding human cooperation.

**Prerequisites:** Math 3. The student should be familiar with calculus, and basic concepts in ordinary differential equations and probability. Programing skills helpful, but not required.

**Grading:** Problem sets (40%), Projects (40%), Attendance & Participation (20%)

**Problem sets:** A total of 4 problem sets will be assigned as take-home exam work during the term, each set biweekly and weighted equally.

**Projects:** Approximately 4 weeks are given to complete the project. The instructor will suggest project ideas in the third week, but you are allowed to propose your own, which has to be approved by the instructor in the fourth week at the latest. Each project presentation is limited to 15 minutes and preferably in the style of TED talks.

**Late policy:** By "deadline" we mean it. On the condition of accepting the penalty for turning in homework late (that is, 8% each additional day), however, an extension of maximum 2 days will be granted on a case-by-case basis.

**Collaboration policy:** Collaborations on problem sets are permitted, but you are required to disclose the names of the other students with whom you collaborated and discussed. You are encouraged to work in groups for course projects (but no more than 2 individuals per project).

**Textbook:** Sigmund, K. (2010). The calculus of selfishness. Princeton University Press.

## Syllabus 16F 10A

**Day 1:** Evolutionary Games: Introduction & Overview
(Problem set 1: Replicator dynamics)
Readings: Nowak, M. A., & Sigmund, K. (2004). Evolutionary dynamics of biological games. *Science*, 303(5659), 793-799.

**Day 2:** Stability Concepts: Nash Equilibrium vs. Evolutionarily Stable Strategy

**Day 3:** Replicator Equations and Its Connection with Ecological Dynamics

**Day 4:** Social Dilemmas of Cooperation
Kollock, P. (1998). Social dilemmas: The anatomy of cooperation. *Annual Review of Sociology*, 183-214.

**Day 5:** Rules for Cooperation
(Problem set 2: Games in finite populations)
Nowak, M. A. (2006). Five rules for the evolution of cooperation. *Science*, 314(5805), 1560-1563.

**Day 6:** Repeated Games
Readings: Binmore, K. G., & Samuelson, L. (1992). Evolutionary stability in repeated games played by finite automata. *Journal of Economic Theory*, 57(2), 278-305.

**Day 7:** Spatial Games
Readings: Nowak, M. A., & May, R. M. (1992). Evolutionary games and spatial chaos. *Nature*, 359(6398), 826-829.

**Day 8:** Adaptive Dynamics
Readings: Dieckmann, U., & Law, R. (1996). The dynamical theory of coevolution: a derivation from stochastic ecological processes. *Journal of Mathematical Biology*, 34(5-6), 579-612.

**Day 9:** Evolutionary Chaos and Branching
(Problem set 3: Games in structured populations)
Readings: Hofbauer, J., & Sigmund, K. (2003). Evolutionary game dynamics. *Bulletin of the American Mathematical Society*, 40(4), 479-519.
Doebeli, M., Hauert, C., & Killingback, T. (2004). The evolutionary origin of cooperators and defectors. *Science*, 306(5697), 859-862.

**Day 10:** Finite Populations
Readings: Nowak, M. A., Sasaki, A., Taylor, C., & Fudenberg, D. (2004). Emergence of cooperation and evolutionary stability in finite populations. *Nature*, 428(6983), 646-650.
Traulsen, A., Claussen, J. C., & Hauert, C. (2005). Coevolutionary dynamics: from finite to infinite populations. *Physical Review Letters*, 95(23), 238701.

**Day 11:** Games on Networks
Readings: Lieberman, E., Hauert, C., & Nowak, M. A. (2005). Evolutionary dynamics on graphs. Nature, 433(7023), 312-316.
Ohtsuki, H., Hauert, C., Lieberman, E., & Nowak, M. A. (2006). A simple rule for the evolution of cooperation on graphs and social networks. *Nature*, 441(7092), 502-505.

**Day 12:** Coevolutionary Games
Readings: Perc, M., & Szolnoki, A. (2010). Coevolutionary games–a mini review. *BioSystems*, 99(2), 109-125.

**Day 13:** Mutation-Selection Equilibrium: Who Laughs Last
(Problem set 4: Modeling human cooperation)

**Day 14:** Integrating Population Genetics
Readings: Antal, T., Traulsen, A., Ohtsuki, H., Tarnita, C. E., & Nowak, M. A. (2009). Mutation-selection equilibrium in games with multiple strategies. *Journal of Theoretical Biology*, 258(4), 614-622.

**Day 15:** Vaccination Dilemma
Readings: Bauch, C. T., & Earn, D. J. (2004). Vaccination and the theory of games. *Proceedings of the National Academy of Sciences of the United States of America*, 101(36), 13391-13394.

**Day 16:** Evolutionary Dynamics of In-group Favoritism
Readings: Masuda, N., & Fu, F. (2015). Evolutionary models of in-group favoritism. *F1000Prime Reports*, 7, 27.

**Days 17-18:** Project Presentations