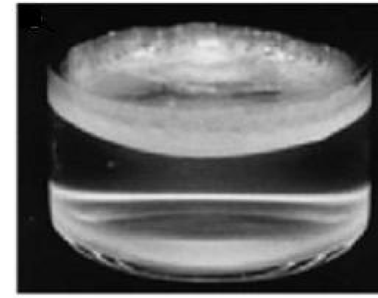
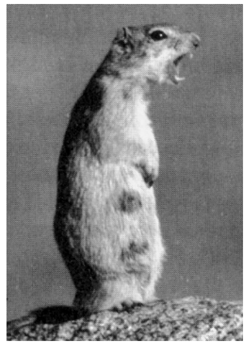
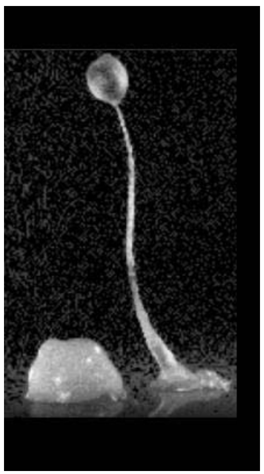
Evolutionary Game Theory

ISCI 330
Lecture 17

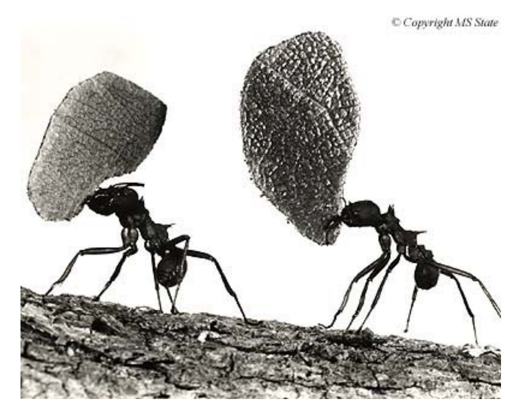










Outline

- A bit about historical origins of Evolutionary Game Theory
- Main (competing) theories about how cooperation evolves
- iPD and other social dilemma games
- Evolutionary Stable Strategy (ESS)
- N-player PD (and other games)
- Simpson's paradox and the role of assortment



Evolution by Natural Selection

- Lewontin’s principles (from Darwin)
  - 1) Phenotypic variation
  - 2) Differential fitness
  - 3) Heritability
- In Evolutionary Game Theory
  - 1) Population of strategies
  - 2) Utility determines number of offspring (fitness)
  - 3) Strategies breed true
- Frequency-dependent selection
  - One of the first examples is Fisher’s sex ratio findings
  - Introduces idea of strategic phenotypes

Ritualized Fighting

		opponent's behaviour	
		Dove	**Hawk**
actor's behaviour	**Dove**	***V*** **/ 2** 5	0
	Hawk	***V*** 10	***V*** **/ 2 -** ***c*** -5

- $V = 10$; $c = 10$
- The rare strategy has an advantage (i.e. frequency dependent selection)
- Hawk-Dove, Chicken, Snowdrift, Brinkmanship
- If $c < V / 2$, then game is PD instead

George Price's Contributions

- Evolutionary Game Theory
  - Concept of an Evolutionary Stable Strategy (ESS)
- Formal description of Natural Selection and Fisher's Fundamental Theorem
- Decomposition of selection at different hierarchical levels using covariance
  - Used to formalize Multilevel Selection Theory

What special circumstances or mechanisms thus favor cooperation? Currently, evolutionary biology offers a set of disparate explanations, and a general framework for this breadth of models has not emerged.

– Sachs *et al*. 2004, **The Evolution of Cooperation**. *QRB* 79:135-160

Main Theories: Evolution of Altruism

- Multilevel Selection

  $\Delta Q = \Delta Q_B + \Delta Q_W$ (Price Equation)

- Inclusive Fitness/Kin Selection
  - $w_{incl.} = w_{direct} + w_{indirect}$

  $\Delta Q > 0$ if $rb > c$ (Hamilton's rule)

- Reciprocal Altruism

  $\Delta Q > 0$ if altruists are sufficiently compensated for their sacrifices via reciprocity (ESS)

Prisoner's Dilemma (PD)

Actor's Fitness (Utility)

		opponent's behavior	
		C	**D**
actor's behavior	**C**	4	0
	D	5	1

Additive Prisoner's Dilemma (PD)

Actor's Fitness (Utility)

		opponent's behaviour	
		C contributes b	**D** contributes 0
actor's behaviour	**C** sacrifices c	$w_0 + b - c$ 4	$w_0 - c$ 0
	D sacrifices 0	$w_0 + b$ 5	w_0 1

- $w_0 = 1$; $b = 4$; $c = 1$

Non-Additive PD

Actor's Fitness (Utility)

		opponent's behavior	
		C contributes b	**D** contributes 0
actor's behavior	**C** sacrifices c	$w_0 + b - c$ (+d) 3	$w_0 - c$ 0
	D sacrifices 0	$w_0 + b$ 5	w_0 1

- $w_0 = 1$; $b = 4$; $c = 1$; $d = -1$

Main Theories: Evolution of Altruism

- Multilevel Selection
  - Predominate models are in terms of public good
- Inclusive Fitness/Kin Selection
  - Predominate models is in terms of individual contributions (b and c)
- Reciprocal Altruism
  - Predominate models in terms of iterated PD

Evolutionarily Social Dilemma Games

- What features do Hawk-Dove and the PD have in common?
  - Cs do better in CC pairs than Ds do in DD pairs
  - Ds do better than Cs in mixed pairs
- Given 4 utility levels (1st, 2nd, 3rd, 4th) how many 2-player, symmetric games are there that capture this idea of "social dilemma"?
- With a partner, find these other games. Can you name them?

6 evolutionarily interesting "social dilemmas"

- How do these games compare in terms of
  - Nash equilibria?
  - Pareto optimality?
  - Is it better to be rare or common?
- Consider populations of strategies rather than 2-players
- Relative vs. Absolute fitness

Common EGT Assumptions

- Population of strategies
- Replicator equations often assume
  - infinite populations
  - continuous (or discrete) time
  - complete mixing (random interactions)
  - strategies breed true (no sex)