The Evolution of Cooperation

The effects on reproductive success of interactions between a helpful donor and a recipient of assistance (redrawn from Alcock 2005 (Animal Behavior: An Evolutionary Approach, 8th Ed)

	Effect on individual Reproductive Success	
Interaction	Donor	Recipient
Mutualism (cooperation)	+	+
Reciprocity	+ (delayed)	+
Altruism	-	+
Selfish behavior	+	-
Spiteful behavior	-	-

If both players benefit from cooperation, why isn't cooperation everywhere—in every interaction where it is possible? If both players benefit from cooperation, why isn't cooperation everywhere—in every interaction where it is possible?

Prisoner's Dilemma

- Two prisoners have information that can put the other away, but they have agreed not to snitch (have agreed to cooperate with one another). The warden approaches each of them (separately), & offers a reduction in sentence for information on the other.
- If both snitch ("defect"), neither wins, because the warden now has information on both that he can use against them.
- If both remain true to their promise with each other ("cooperate"), the warden knows no more than he did, and they each come out farther ahead than if both defected.
- However, if one cooperates and one defects, the cooperator loses maximally, and the defector gains maximally, because the defector ("snitch") has bargaining power for having given up information, but nothing is known of his own illegal activities. The cooperator is known to be guilty, and has no bargaining power.

Using game theory to predict ESS

- Game theory formalizes the strategic possibilities between two "players" over time. Prisoner's Dilemma is the best known of the "games," and Axelrod and Hamilton (1981) used it to model the evolution of cooperation in a previously asocial system.
- Basic premise and assumptions: two individuals can each either cooperate or defect from an interaction. The payoff to a player is in terms of the effect on its fitness (survival and fecundity). No matter what the other does, the selfish choice of defection yields a higher (average) payoff than cooperation. But if both defect, both do worse than if both had cooperated.
- The individuals can be almost anything: badgers, clams, humans, bacteria. Following rules dictated by game theory to attain an ESS requires neither consciousness nor a brain. But having these attributes makes game-playing behavior richer and more complex.

Prisoner's Dilemma payoff matrix: figure 1 in A&H 1981)

Player A \ Player B	C Cooperation	D Defection
C Cooperation	R=3 Reward for mutual cooperation	S=0 Sucker's payoff
D Defection	T=5 Temptation to defect	P=1 Punishment for mutual defection

The game is defined by

$T > R > P > S$, and

$R > (S + T) / 2$.

Axelrod and Hamilton's innovation: iterated interactions

- If you're never going to interact with the other player again, the only stable strategy is to ALWAYS DEFECT.
- Furthermore, if there is a known number of interactions, whether or not this is the last one, defection is the only stable strategy.
- If the two players have a probability, w, where $0 < w < 1$, of meeting again (and making these choices again), the ESS changes: the decision is now probabilistic. The stable strategy may be based on determining the probability that the other guy will cooperate or defect as a function of the history of the interaction so far.

If there is probability of meeting again, what is an ESS?

- Over 75 models were submitted by economists, political scientists, mathematicians, biologists, and physicists and run against each other in a computer simulation. The winner: **TIT FOR TAT** (Cooperate on the first move, then do whatever your opponent did on the previous move for all subsequent interactions). Put another way: cooperation based on reciprocity. What are this strategy's strengths, in terms of robustness?

What needs to be true for cooperation to evolve?

In nature, what determines the probability of meeting again?

What additional parameters affect game-theoretic decisions?

- Do individuals have the ability to punish cheaters/defectors through ostracism from the social group?
- What is the "shadow of the future?" (How likely is the game to end on the next move?) This term arose when game theory was being applied primarily to war games during the Cold War (by, among others, John Nash): if defection of one player at any moment means nuclear annihilation, how does that alter the stable strategy? (PERMANENT RETALIATION (cooperate until your opponent defects, then defect for ever after) may become stable.)
- How likely is noise in the system? (That is, how likely are you to misread the other player's signal?)

Evolution of Cooperation Workshop

For each of three rounds (rules below), you and a partner will play 50 iterations of Prisoner's Dilemma, with the numerical pay-offs as indicated in Axelrod and Hamilton 1981
(see fig 1: S = 0, P = 1, R = 3, T = 5).

In each round, keep track of:

Strategies: Identification of both strategies played

Quantitative:
- Which strategy won?
- What was total score of each strategy (A and B)?

Qualitative:
- Assess your and your opponent's strategy on the basis of
    - Robustness
    - Stability
    - Initial viability
- What strategies won? What strategies seemed like they would win, but didn't? What patterns emerged? Were things going well for your strategy, until something happened…?

Three rounds of game:

I. Play one of the following five strategies; establish your strategy with your die:
   1. RANDOM (use dice each time: 1 – 3: C; 4 – 6: D)
   2. TIT FOR TAT (starts with C)
   3. ALL C
   4. ALL D
   5. C & D ALTERNATE (start with C, then alternate between strategies on each iteration)

   When you are done, write your quantitative results on board. When everyone is done with this first round, we will compare results (as for all future rounds)

II. Play top two strategies from round I, plus additional ones that have simple algorithms, which we generate. How do we assess which were the top two strategies from round I?

III. Play whatever strategy, however variable, you want, except that you can't discuss with your opponent what s/he is going to do next.

How does the known number of iterations affect the outcome of this game?