# Punishment, Rational Expectations, and Relative Payoffs

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# An Experiment

- 2 subjects play anonymously
- Players have only 2 choices
- Choices are made simultaneously

| | | Player 2 | |
|---|---|---|---|
| | | A | B |
| Player 1 | A | $x_1, x_1$ | $x_3, x_2$ |
| | B | $x_2, x_3$ | $x_4, x_4$ |

# An Experiment

- Game 1

- Expected outcome:
  - Players choose B

- Results:
  - B selected in 74% of games

| Player 1 | | Player 2: A | Player 2: B |
|---|---|---|---|
| | A | 3, 3 | 0, 5 |
| | B | 5, 0 | 1, 1 |

# An Experiment

- Game 2
- Expected outcome:
  - Players choose A
- Results:
  - B selected in 72% of games

| Player 1 \ Player 2 | A | B |
|---|---|---|
| A | 4, 4 | 1, 3 |
| B | 3, 1 | 0, 0 |

# An Experiment

- Authors concluded that utility is driven by “the need to *maximize the difference* between one’s self and the other player”

- Minas, JS et al. **1960**. Some descriptive aspects of two-person non-zero-sum games II. *Journal of Conflict Resolution* 4(2):193-197

# Questions

- Are assumptions of rational choice theory correct?
  - Do people really only maximize payoffs?
  - Is rational choice theory framed in evolutionary terms?

- What does evolutionary biology tell us?
  - Natural selection is driven by *relative* fitness

- How do absolute models compare to relative models?

# The simulation model

- Payoff maximization with **local interactions**
- Populations structured in **social networks**
- Prisoners dilemma with punishment
- Evolutionary algorithm with mutation

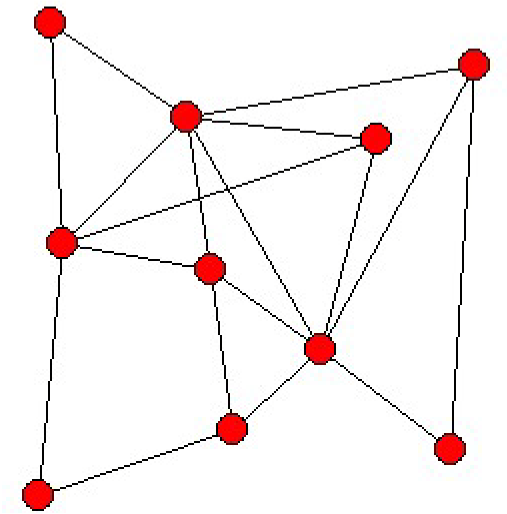
# Continuous prisoners dilemma

- Not limited to 2 choices
  - Choose a cooperation level *x* on [0,1]
- Given a game between *i* and *j*
  - $p_i = 1 - x_i + r(x_i + x_j)/2$
- The dilemma
  - $p_i$ is maxed when $x_i = 0$
  - $(p_i + p_j)$ is maxed when $x_i$ and $x_j = 1$

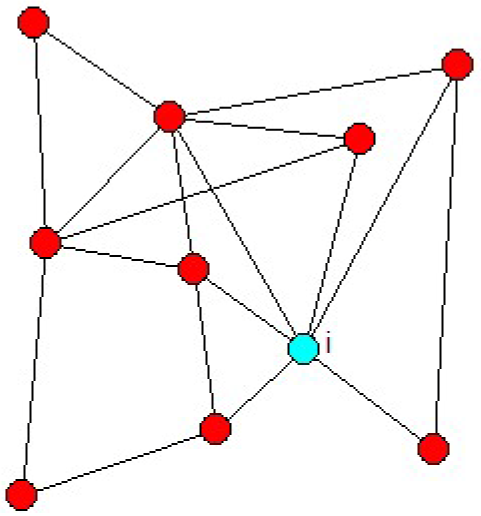
# Altruistic punishment

- Punishment is known to induce cooperation in laboratory experiments
- A reduction in payoffs to punish another with no material benefit in return
- When $k$ punishes $j$
  - $k$ is charged a cost of $c$
  - $j$ is charged a fine of $cM$

# Simulation example

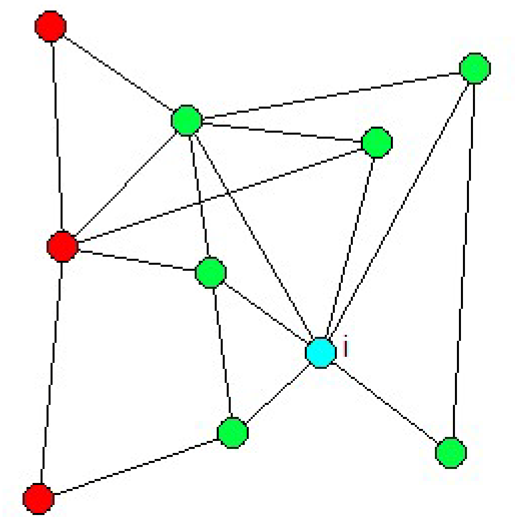


# Simulation example



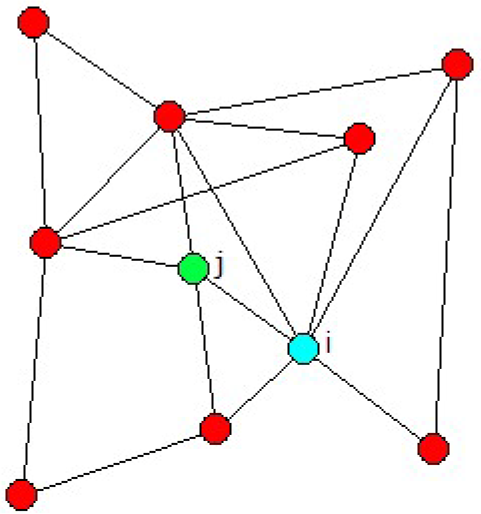

- *i* is selected to initiate a game

# Simulation example



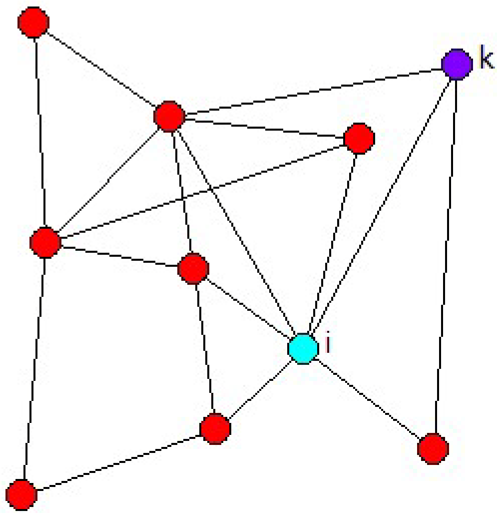

- *i* interacts only within a local neighborhood

# Simulation example




- $i$ randomly selects $j$ to play with
- $i$ and $j$ contribute $x_i$ and $x_j$ respectively
  - $x_i + x_j = G$
- Each gets a payoff
  - $p_i = (1\text{-}x_i) + rG/2$
  - $p_j = (1\text{-}x_j) + rG/2$

# Simulation example




- *i* randomly chooses a neighbor *k* to evaluates *i*
- If *i*'s offer was sufficient nothing happens
- If *i*'s offer was too low *k* punishes *i*
  - $p_{\mathrm{k}} = p_{\mathrm{k}} - c$
  - $p_{\mathrm{i}} = p_{\mathrm{i}} - cM$

# Networks used

| Network Type | Description of Neighbors | Number of Neighbors |
|---|---|---|
| Ring | Left, right | 2 |
| Von Neumann | Left, right, up, down | 4 |
| Hexagonal | Left, right, diagonals | 6 |
| Moore | Left, right, up, down, diagonals | 8 |
| Complete | All other agents | $N$-1 |

# Behavior models

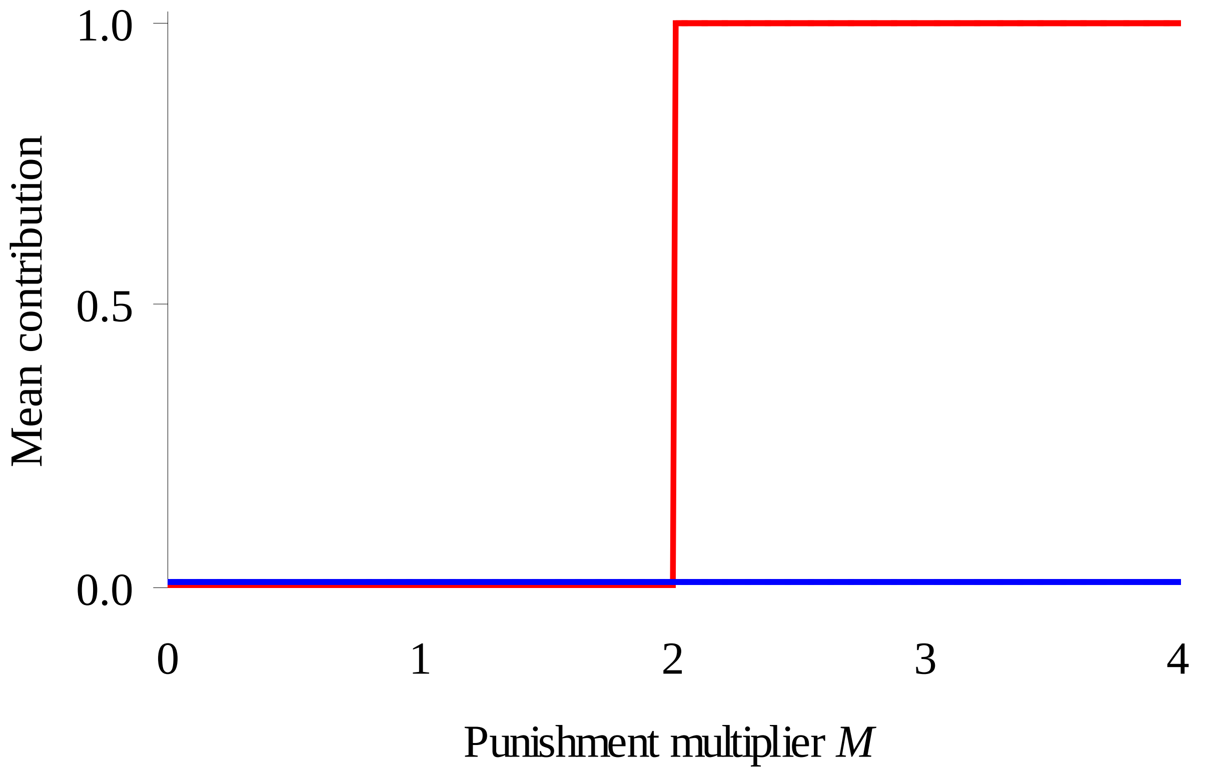
## Economic model

- Agents maximize *p*
- Agents never punish
- No punishment = no cooperation

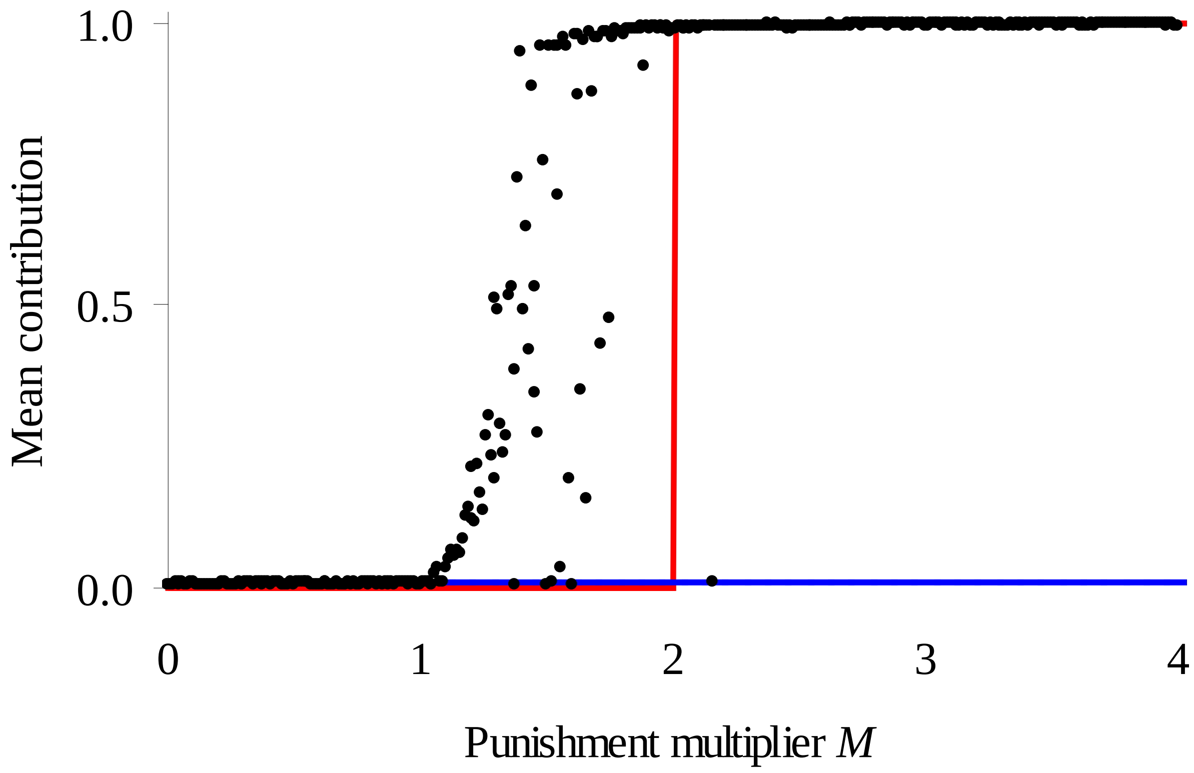
## Biological model

- Agents maximize $p/P_n$
- Agents punish at $M > n$
- Punishment results in cooperation

# Linear Network - Predictions



# Linear Network - Results



# Results ($N$=400)

**value of $M$ at which punishment drives the population to cooperate**

| **Network Type** | **Economic Expectation** | **Biological Expectation** | **Simulation Result** |
|---|---|---|---|
| Ring | Never | 2 | 1.5 |
| Von Neumann | Never | 4 | 1.8 |
| Hexagonal | Never | 6 | 2.2 |
| Moore | Never | 8 | 2.8 |
| Complete | Never | $N - 1$ | Never |

# Why is this important?

- International treaties are often designed to convert a dilemma to a “win-win” scenario

| | | Player 2: A | Player 2: B |
|---|---|---|---|
| Player 1 | A | 3, 3 | 0, 5 |
| Player 1 | B | 5, 0 | 1, 1 |

→

| | | Player 2: A | Player 2: B |
|---|---|---|---|
| Player 1 | A | 4, 4 | 1, 3 |
| Player 1 | B | 3, 1 | 0, 0 |

- If relative payoffs drive behavior the treaty has no effect

# Conclusion

- Behavior in networked populations is better predicted by a biological, relative payoff model
- The importance of relative vs. absolute payoffs is dependent on network topology
- If relative payoffs drive behavior, restructuring payoffs may not have intended effects

# Thank you

- Questions?
- Contact:
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