

# THE EVOLUTION OF COOPERATION IN A COMPETITIVE WORLD



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## I Motivation

### Biological:

- World abounds with cooperation (from single cells coming together in multi-cellular organisms, to social insects and human society), but natural selection fails to explain how it would evolve.
- Natural selection should promote selfishness at the expense of others

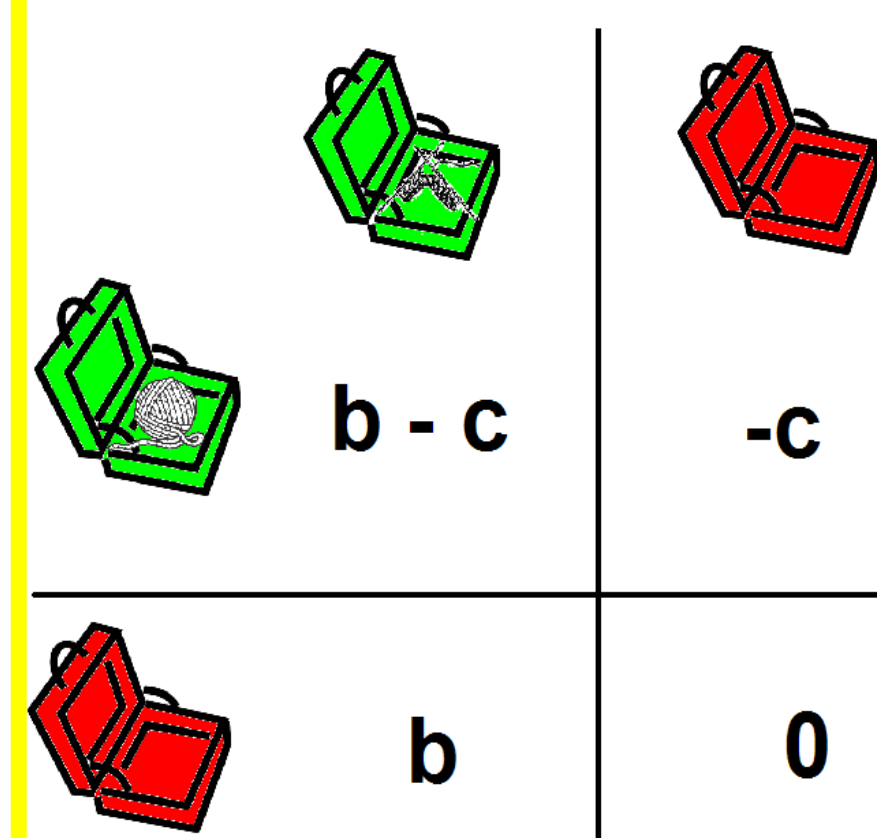
### Social:

- Humans cooperate in many games where rational agents would defect (i.e. Prisoner's dilemma)
- Humans are often willing to sacrifice their own well being for the well being of others or society at large

Use evolutionary game theory to study cooperation!

## II Cooperation

- Two meanings: Evolutionary and Social
- Evolutionary: Behaviors that benefit members of the same species
- Social: choices that are beneficial to the society
- Often a trade off between helping the whole and helping the self



### Prisoner's dilemma

- One of many possible games
- A rational player always defects, but humans often cooperate
- Popular game in current EGT.

## III Evolving cooperation

### Complex

- Kin selection: favor your own family members
- Direct reciprocity: remember repeated interactions and cooperate with those that cooperate with you
- Indirect reciprocity: keep track of agents reputation and cooperate with those that have good reputation
- Social networks: certain social network structures favor cooperators

### Simple

- Group selection: selection acts on both individuals and groups; groups of cooperators fare better than groups of defectors
- Highly viscous environment: children do not stray too far from parents
- Green-beard effect?

## IV Green-beard effect

- Arbitrary tag used to guide behavior
- Allows dual strategy, one for same-tag (In-group) and one for different-tag (Out-group)
- Cooperation with same-tag, defection against different-tag
- Known as Ethnocentrism in humans
- Observed in: annual plants, ants, and human placenta

Strategy	In-group	Out-group
Selfish	Defect	Defect
Traitor	Defect	Cooperate
Ethnocentric	Cooperate	Defect
Humanitarian	Cooperate	Cooperate

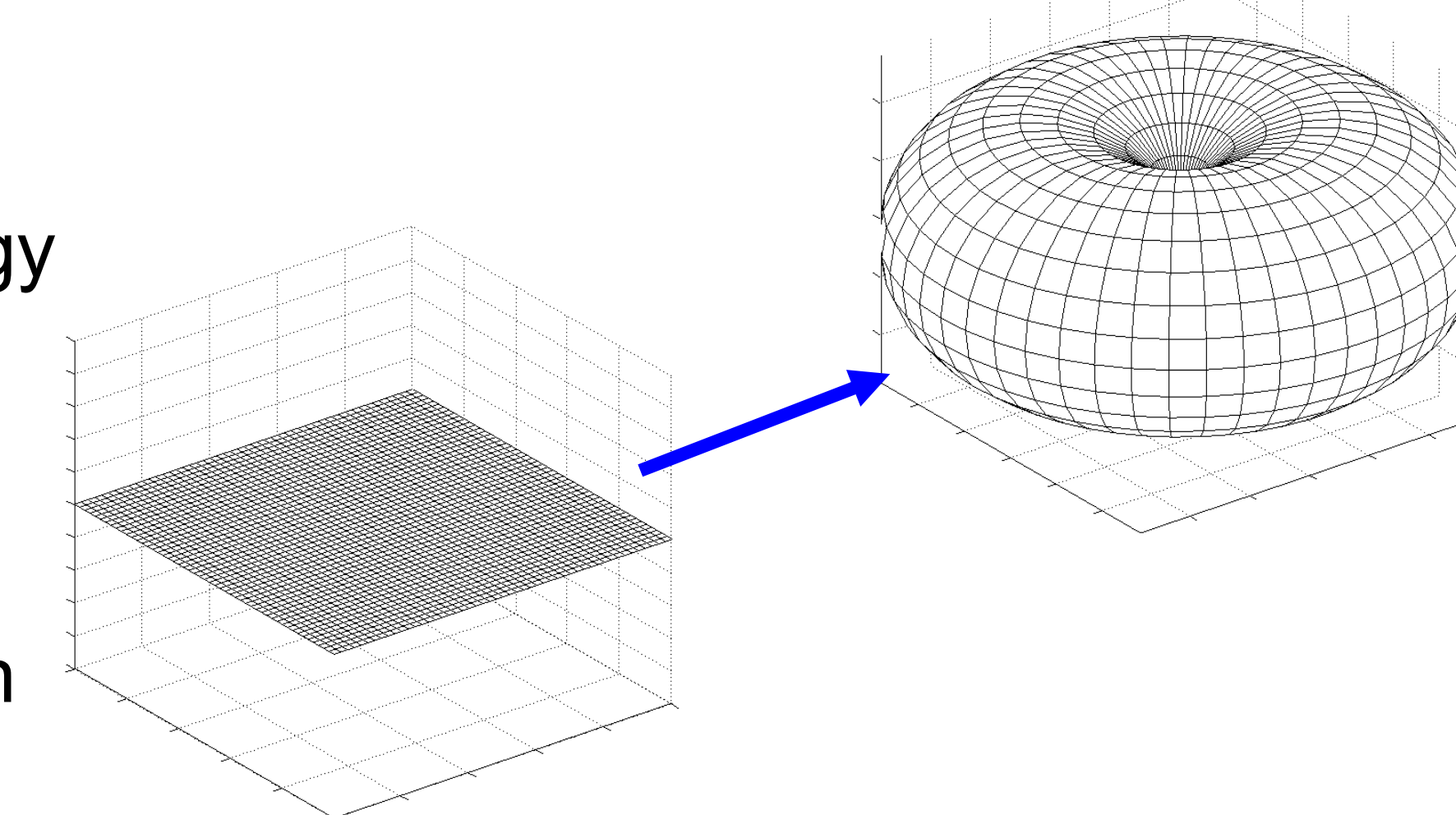
## V Simulation

### Basics

- Toroidal grid lattice (50 x 50)
- Agent characteristics:
  - Reproductive potential
  - Tag-less** models:
    - Strategy
  - Tag** models:
    - In-group strategy
    - Out-group strategy
    - Tag (1, 2, 3 or 4)
- Grid is initially empty
- Tracked data:
  - Interaction results
  - Strategy distribution

### Procedure for each cycle

- Interaction
- Reproduction
- Death
- Child Placement



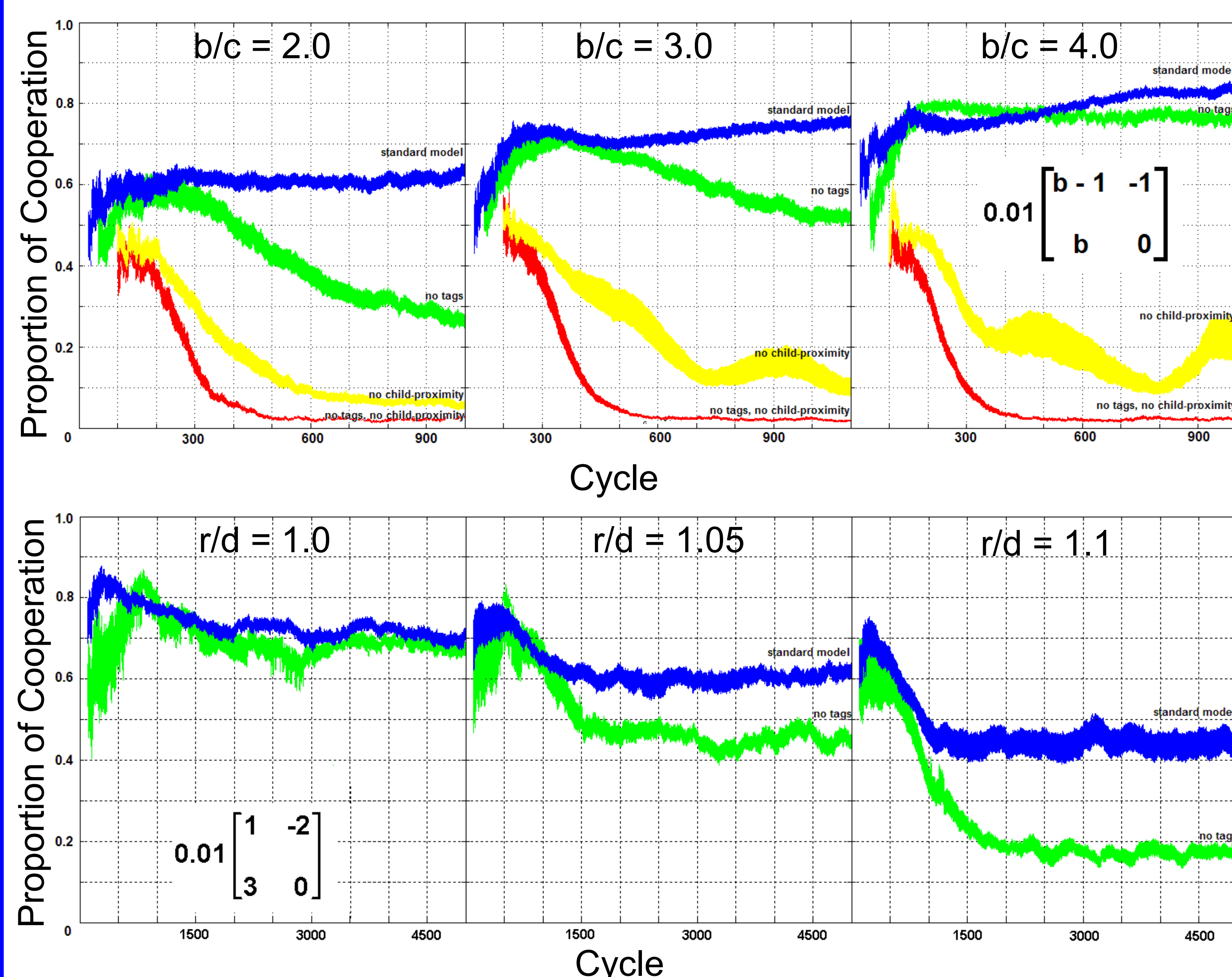
## VI Some Math

- General utility function for an agent with strategy **a** interacting with other agents with strategy vectors **b**:

$$U(\mathbf{a}; \mathbf{b}, r, p_b) = r\mathbf{a} \cdot (\mathbf{P} + \mathbf{Q})\mathbf{a} + p_b \mathbf{a} \cdot \mathbf{P}\mathbf{b}$$

- $r$  - chance of interacting with an identical agent;  $p_b$  - chance of interacting with an agent with strategy **b**; **P, Q** - game matrices
- Utility function is general enough to cover any two-player game (not only PD) and provides predictions for many cooperation mechanisms (not only Green-beard effect)
- Green-beard effect:**  $r$ - $p$  symmetry (blue) must be broken to give cooperators an edge over defectors in a tag environment; green-beards need aid of another mechanism to break  $r$ - $p$  symmetry

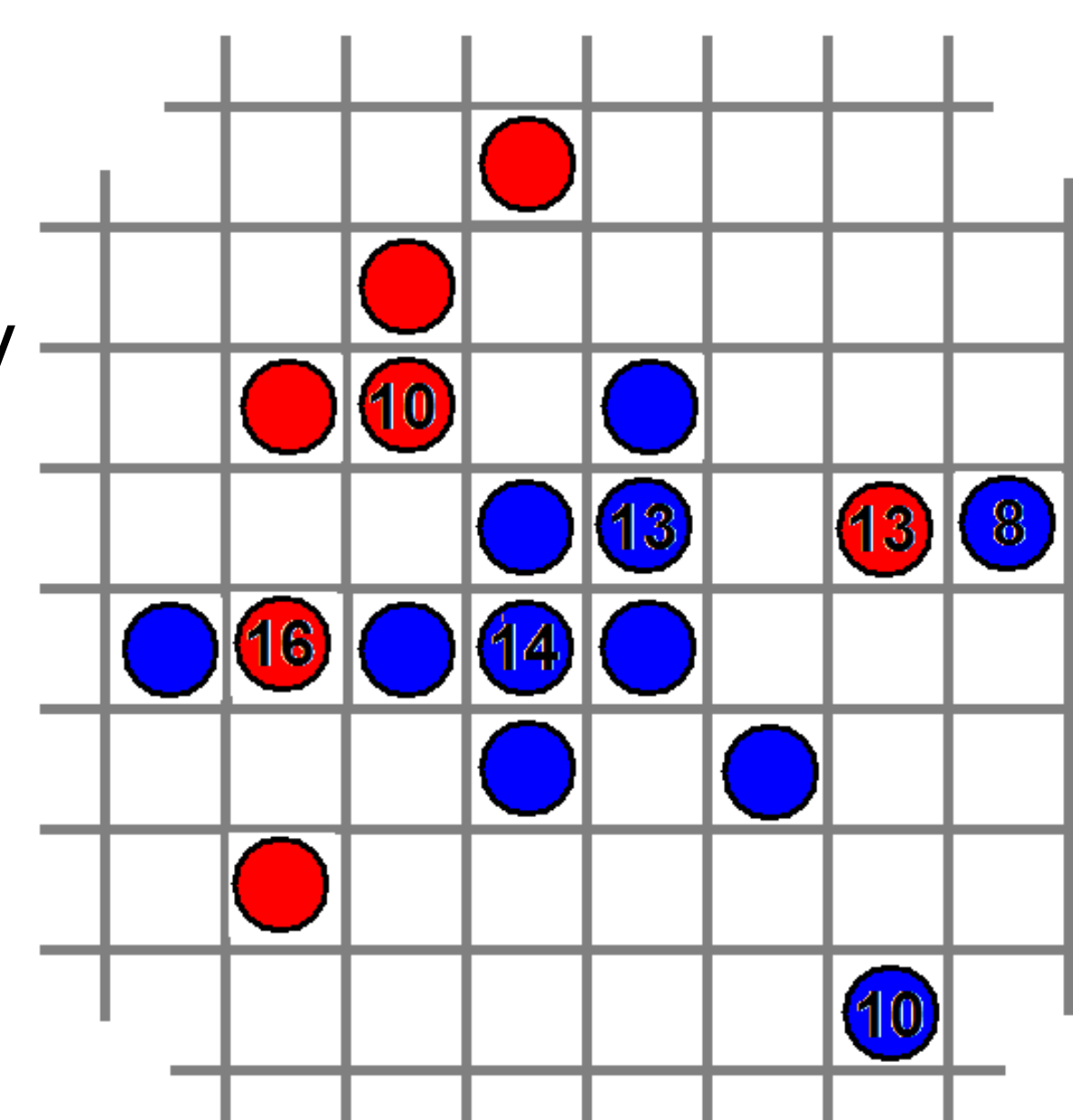
## VII Results



- Proportion of cooperative interactions averaged over 30 simulations vs. evolutionary cycle
- Top plot varies the cost to benefit ratio of the game
- Bottom plot varies austerity of environment
- Blue – tag and child-proximity (CP); green – no tag but CP; yellow – tag but no CP; red – no tag and no CP
- Line thickness indicates 1 SE around the mean.

### Key observations:

- Tags are not sufficient for cooperation, child-proximity is needed
- Higher  $b/c$  lowers the importance of tags
- Low growth rates (high environmental austerity) increase proportion of cooperation



## VIII Conclusion

- Green-beard effect cannot emerge as the primary mechanism for creating cooperation; it must co-evolve with other mechanisms
- Greater benefit for equal cost reduces the impact of the green-beard effect
- Social context:** ethnocentrism in modern humans is not essential for cooperation and could be overcome.
- Greater environmental austerity discourages selfish behavior
- Future directions:** analyze cooperation-defection transitions, search for simpler methods for evolving cooperation, and explore evolutionary games on dynamic graphs

## IX References

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