

# Cooperation, Norms and Conflict: Towards Simulating the Foundations of Society

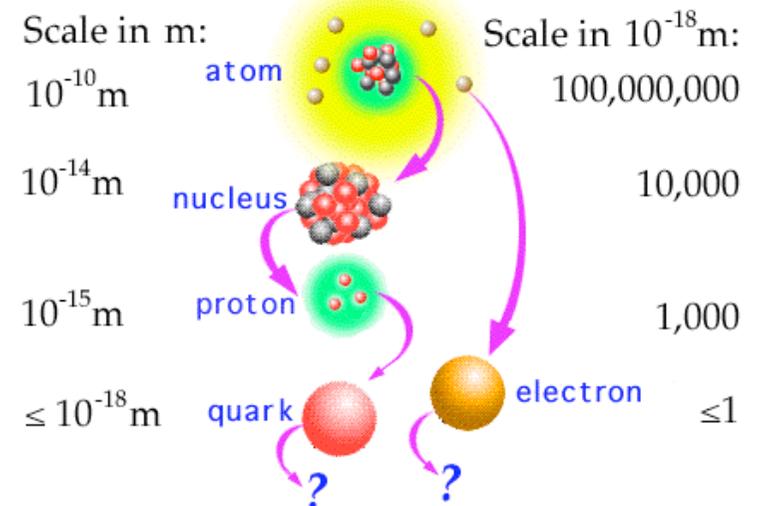
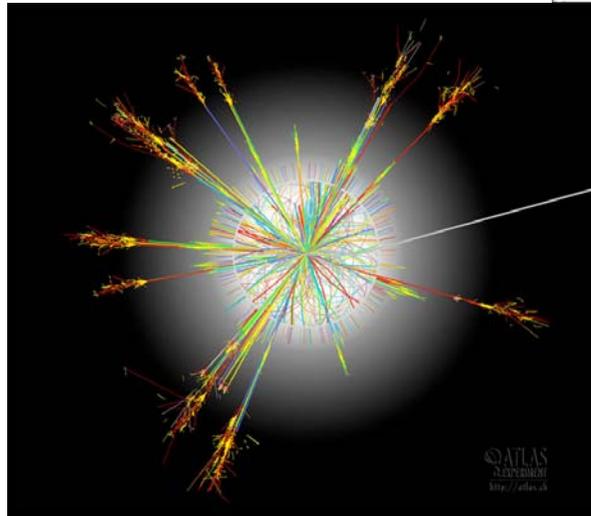
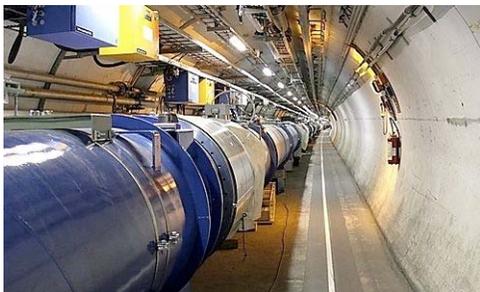
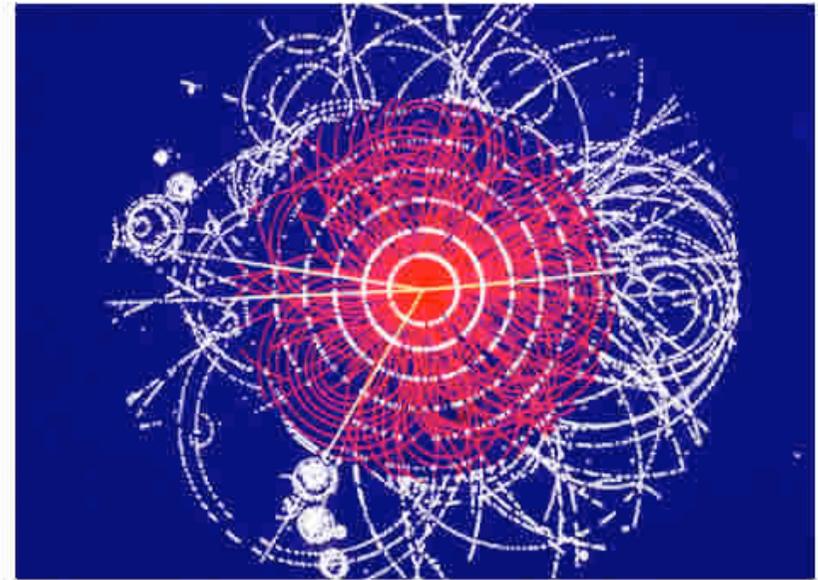
Dirk Helbing,

with Wenjian Yu, Anders Johansson, Carlos Roca, Thomas Chadeaux  
and other collaborators in Zurich, Dresden, and all over the world

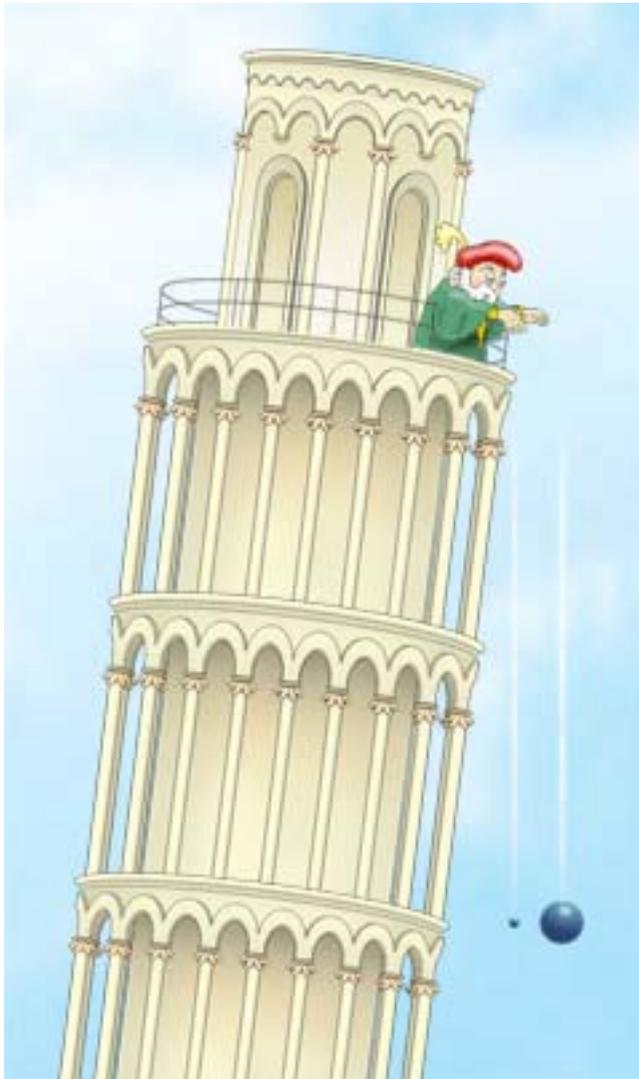




# Can We Understand a System from Elementary Processes?



# The Need of Simplification and Abstraction



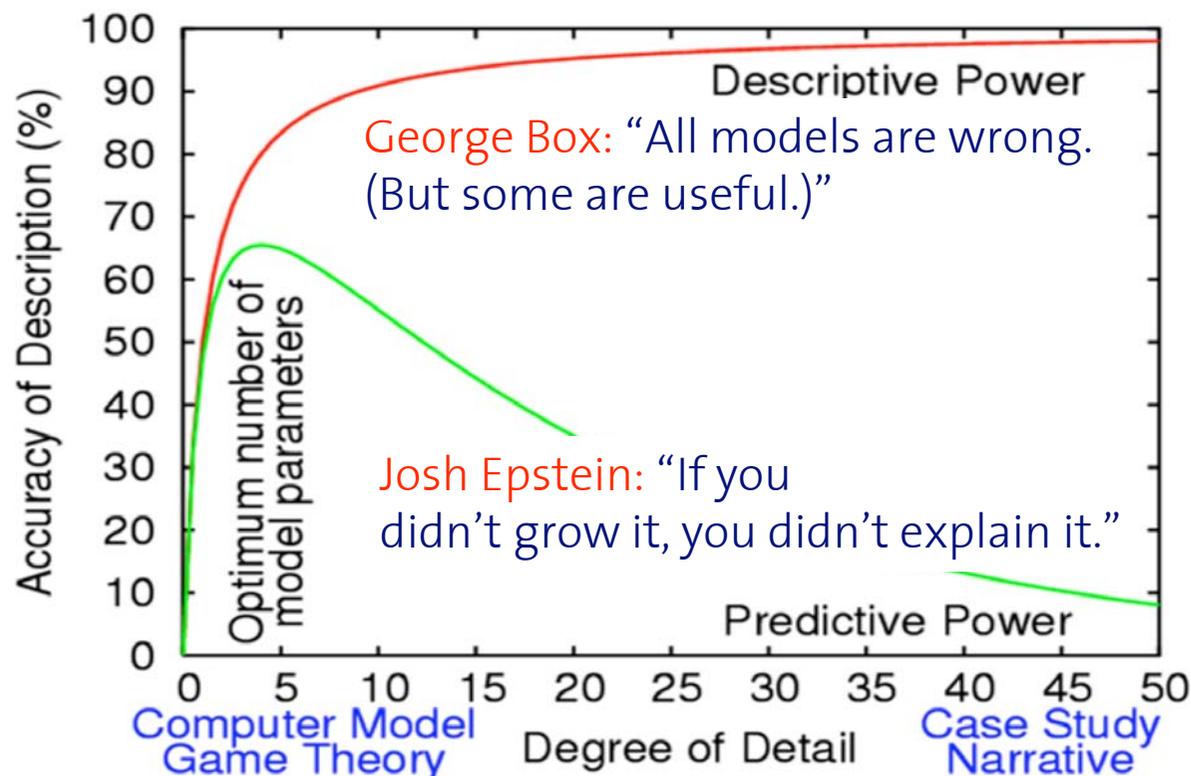
## Equations For A Falling Body



"Y'know, Henry, I had no idea it would be so fun to go skydiving with a physicist."

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## On Simple and Detailed Models



The more parameters a model has, the more difficult it is to fit them all exactly. This may affect the accuracy of predictions.

Many social systems are so complex, that the relevant variables and parameters involved are hard to identify and to measure. I will, therefore, study a few simple, measurable systems (leaving, for the time being, complex issues like meanings, values, historical aspects, and other behavioral dimensions aside), hoping that one can learn something more general from the principles observed in these examples.

## Some Fundamental Phenomena in Social Systems

- **Homophily** (interaction with similar people) and social agglomeration
- **Social influence**: Collective decision making and behavior, voting behavior
- **Cooperation** in social dilemma situations
- **Group identity**: Group formation, group and crowd dynamics, coalition formation, social movements, organizations
- **Social norms** and conventions, conformity, integration, social roles and socialization, social institutions, evolution of language and culture
- **Social differentiation**, inequality, and segregation
- **Social structure**, hierarchical organization, etc.
- **Deviance** and crime
- **Social exchange**, trading, market dynamics
- **Conflicts**, violence, and wars

## Model Ingredients: Elementary Properties of Individuals

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- Birth, death, and reproduction
- Individuals need resources (e.g. eat and drink)
- Competition, fighting ability
- Toolmaking ability, possibility to grow food, hunt etc.
- Perception
- Curiosity, exploration behavior, ability for innovation
- Emotions
- Memory
- Mobility and carrying capacity
- Communication
- Teaching ability
- Possibility of trading and exchange

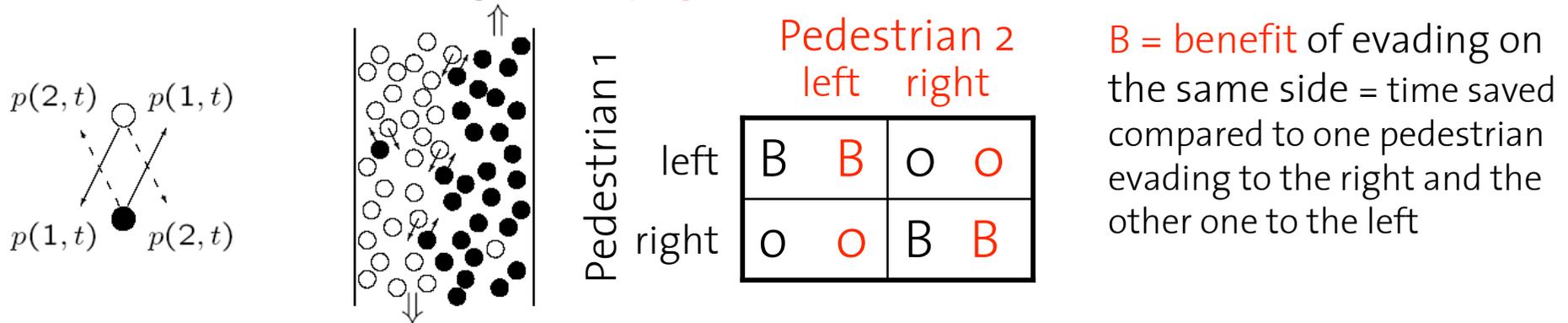
**Goal:** Derive the fundamental phenomena from these elementary properties

# Evolutionary Game Theory: How Spatial Interactions, Migration, Social Inequality, Globalization and Heterogeneous Preferences Can Change the World in Surprising Ways



## Self-Organization of A Behavioral Convention

The result of a social interaction between two individuals is characterized by the “payoff”



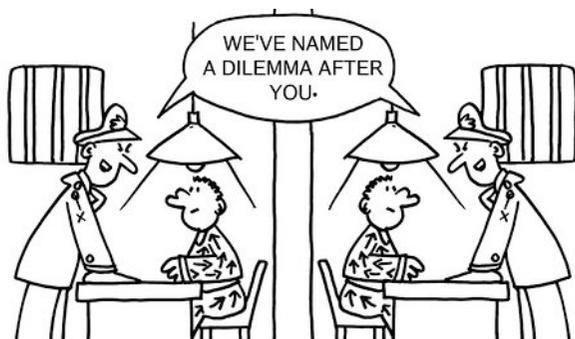
If  $p(1,t)$  denotes the probability of pedestrians to evade on the right and  $p(2,t)$  to the left, the **expected payoff** (“success”) is  $S(i,t) = Bp(i,t)$ , when using strategy  $i$ . The **average success** of pedestrians is  $A(t) = p(1,t)Bp(1,t) + p(2,t)Bp(2,t)$ , where  $p(2,t) = 1 - p(1,t)$ . Due to strategy changes (**success-driven imitation**), the proportion of strategy  $i$  grows proportionally to the difference between the expected success and the *average* expected success:  $dp(i,t)/dt = r [S(i,t) - A(t)]p(i,t)$

$$dp(i,t)/dt = -2rB[p(i,t)-1/2] p(i,t) [1-p(i,t)] \quad i=1: \text{right}, i=2: \text{left}$$

Only the stationary solutions  $P(i,t)=0$  or  $1$  are stable, i.e. one evading side will become a **behavioral convention** (Helbing, 1990, 1991, 1992)

## The Prisoner's Dilemma

The prisoner's dilemma game has served as prime example of strategic conflict among individuals. It assumes that, when two individuals cooperate, both get the “reward”  $R$ , while both receive the “punishment”  $P < R$ , if they defect. If one of them cooperates (“C”) and the other one defects (“D”), the cooperator suffers the “sucker’s payoff”  $S < P$ , while the payoff  $T > R$  for the second individual reflects the “temptation” to defect. Additionally, one typically assumes  $S+T < 2R$ .



		Player 2	
		Cooperate	Defect
Player 1	Cooperate	$R_1 \ R_2$	$S_1 \ T_2$
	Defect	$T_1 \ S_2$	$P_1 \ P_2$

For example:

$$S_1 = S_2 = S = -5$$

$$P_1 = P_2 = P = -2$$

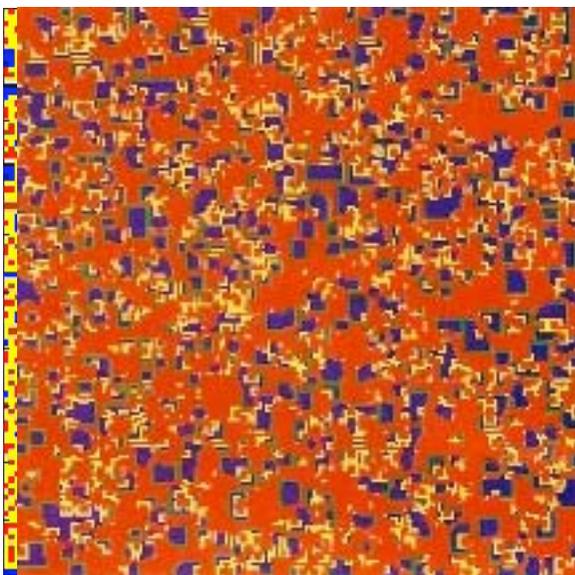
$$R_1 = R_2 = R = -1$$

$$T_1 = T_2 = T = 0$$

Many “social dilemmas” are of a similar kind (see public goods game)

## Start with the Spatial Prisoner's Dilemma...

Nowak and May (1992) have extended the prisoner's dilemma to simultaneous **spatial interactions** in an  $L \times L$  grid involving  $L^2$  players, assuming that each player would have binary **interactions with  $m=8$  nearest neighbors**, and would afterwards **imitate the strategy C or D of the most successful neighbor**, if he or she performed better. Computer simulations for  $R=1$  and  $P=S=0$  show **“chaotic” pattern formation phenomena** in a certain parameter range of  $T$ .



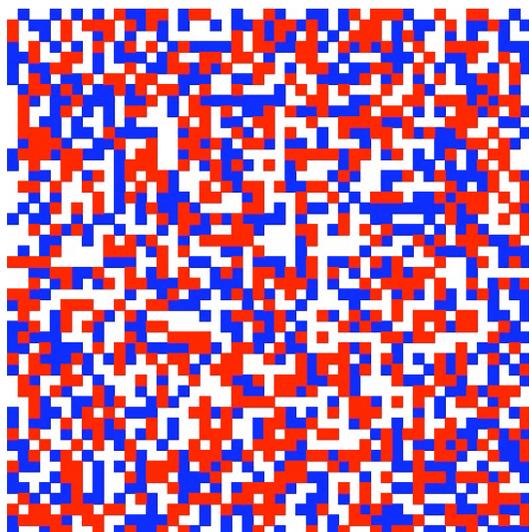
For  $R=1$  and  $P=S=0$  Nowak and May have found that big clusters of defection shrink for  $T < 1.8$ , while for  $T > 2$ , cooperative clusters do not grow, and in between, both **cooperative and defective clusters would expand, collide, and fragment**.

Source: M. A. Nowak and R. M. May, Nature 359, 826 (1992).

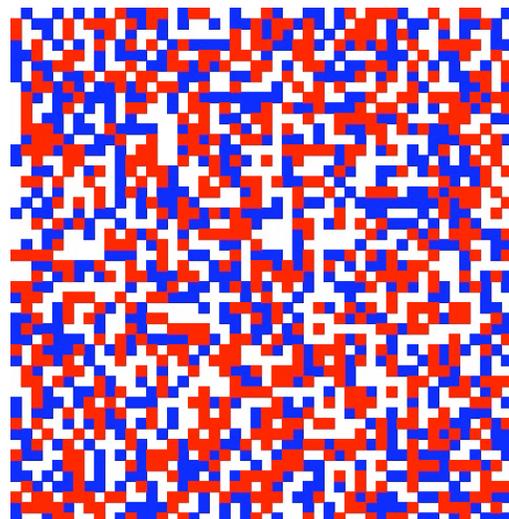
blue = cooperator, red = defector, yellow = turned to defection, green = turned to cooperation

# Imitation and Success-Driven Motion, Separately and Together

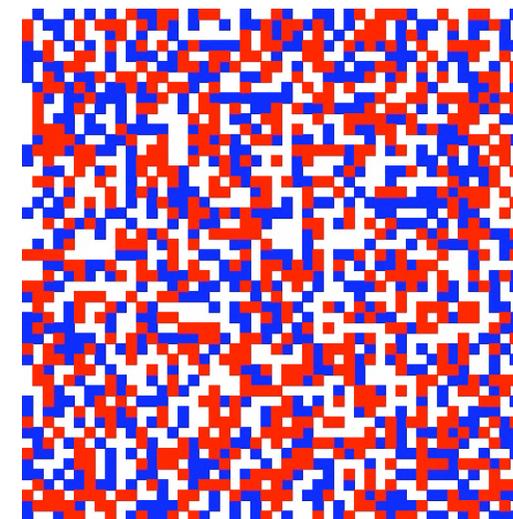
$P = 0$   
 $R = 1$   
 $S = 0$   
 $T = 1.4$



imitation only

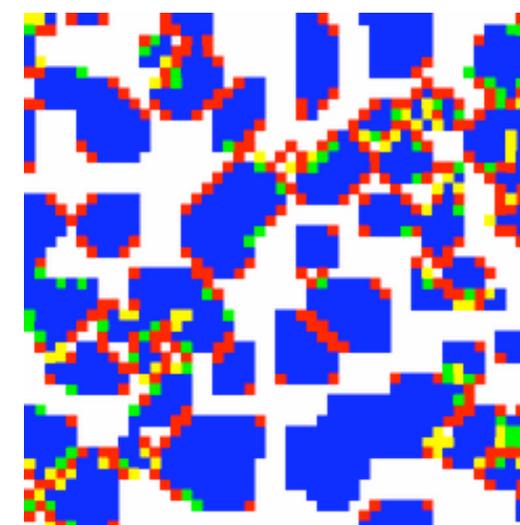
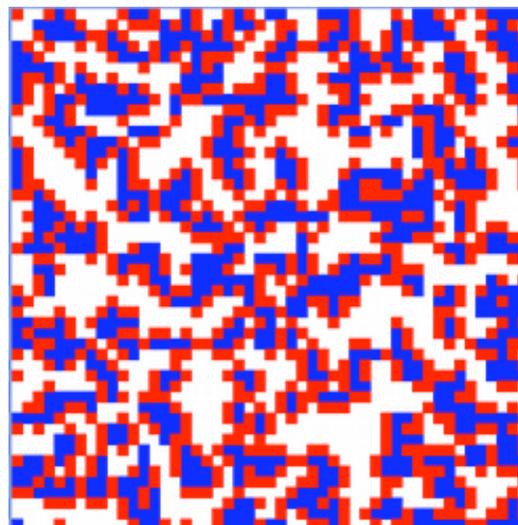


migration only



imitation & migration

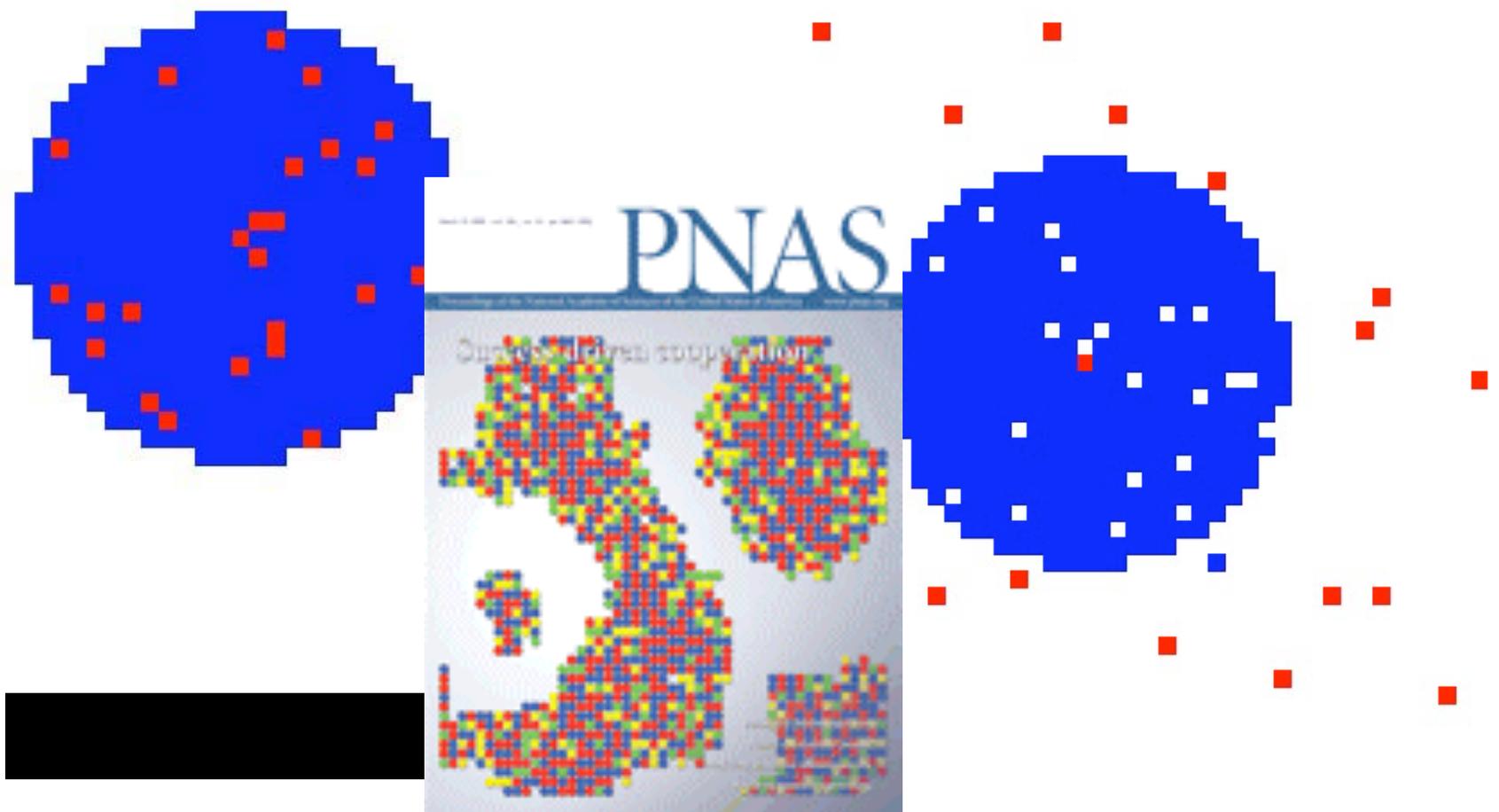
blue = C  
red = D



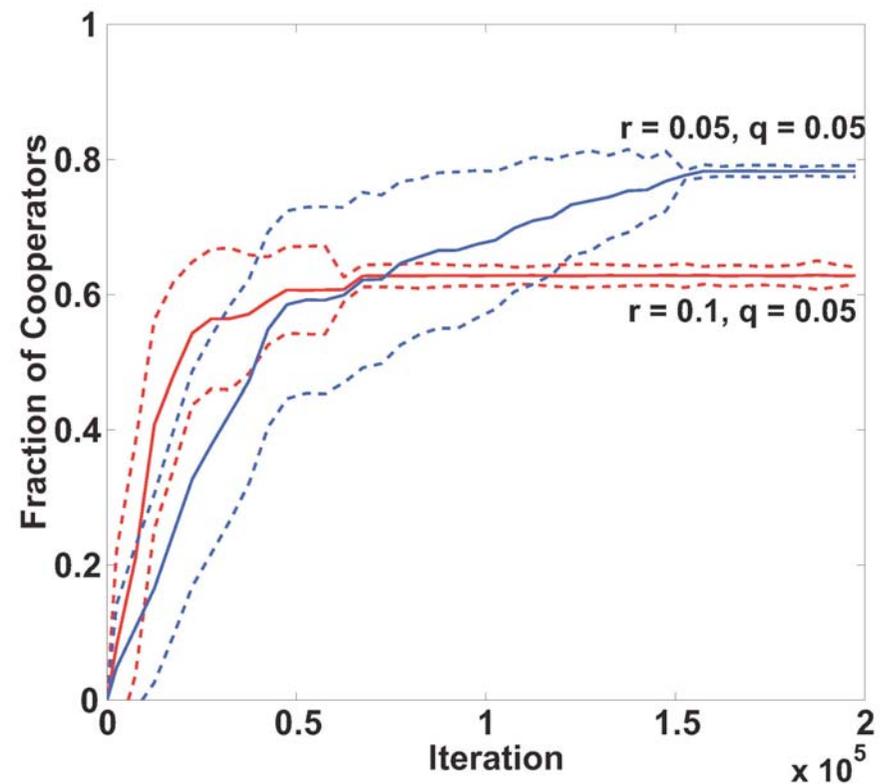
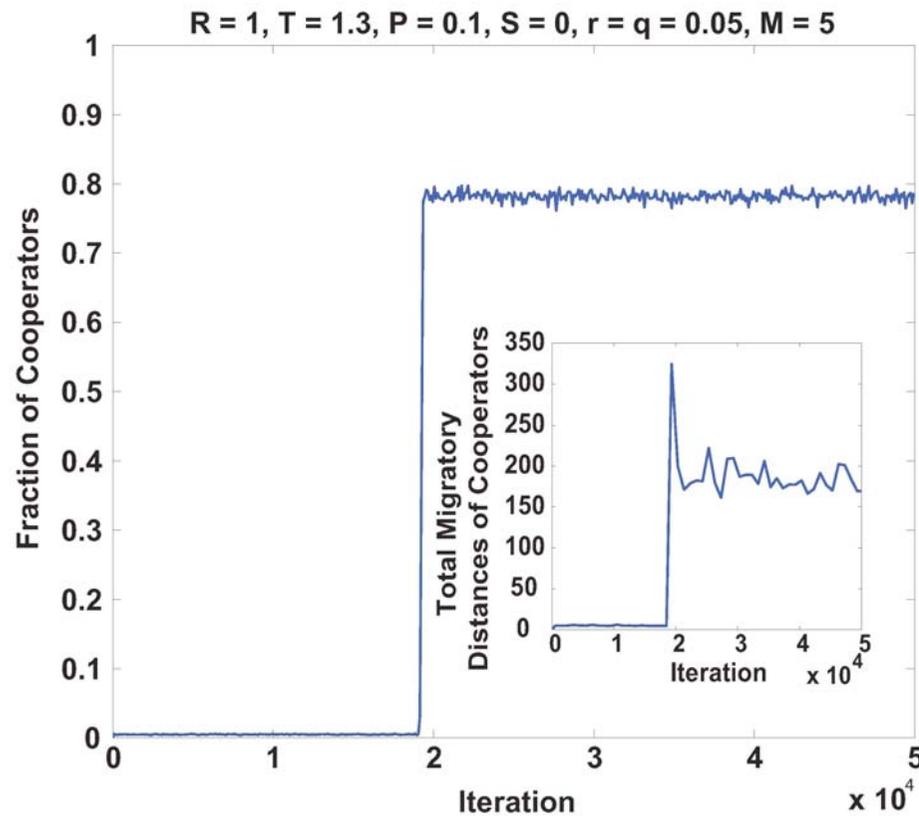
# The Breakdown and Outbreak of Cooperation

Red, yellow: defectors (cheaters)

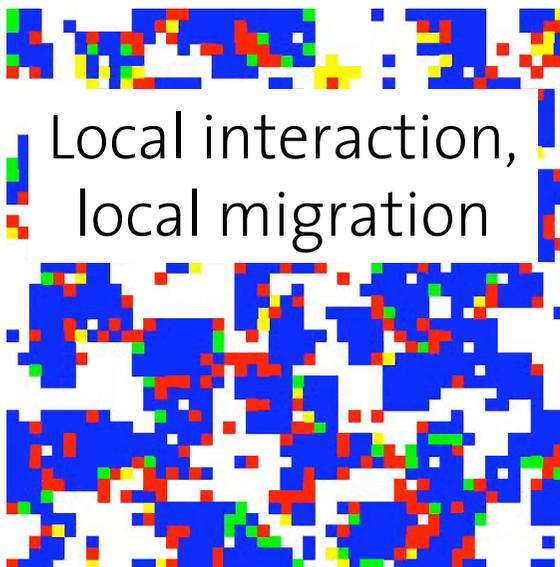
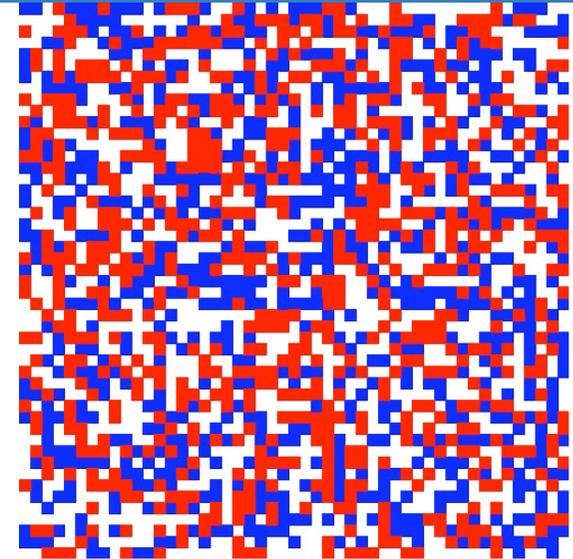
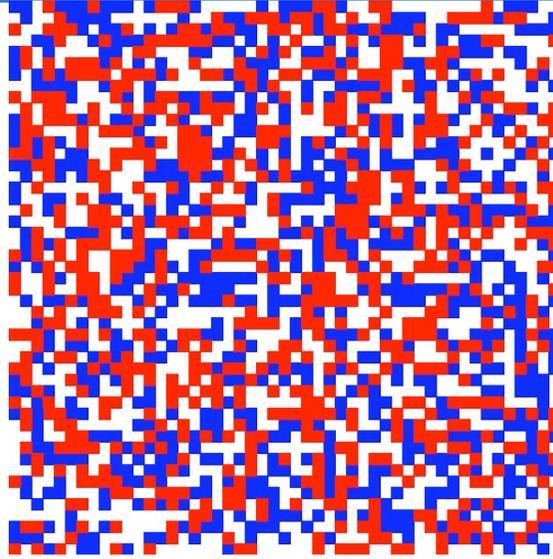
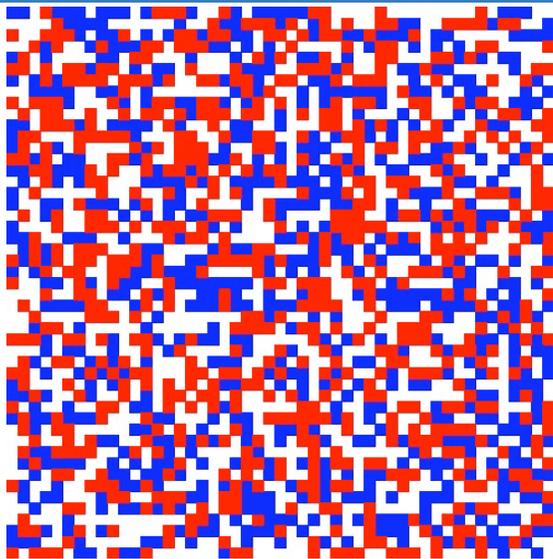
Blue, green: cooperators



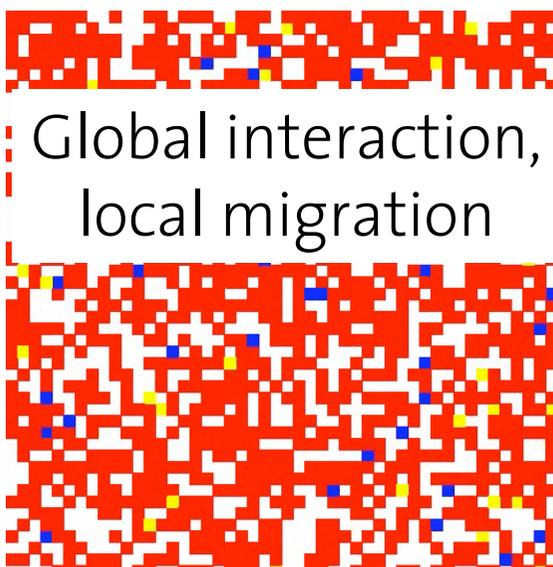
# Time-Dependence of Transition of Predominant Cooperation



## Does Globalization Endanger Social Cooperation?



Local interaction,  
local migration



Global interaction,  
local migration



Global interaction,  
global migration

## Intermediate Summary

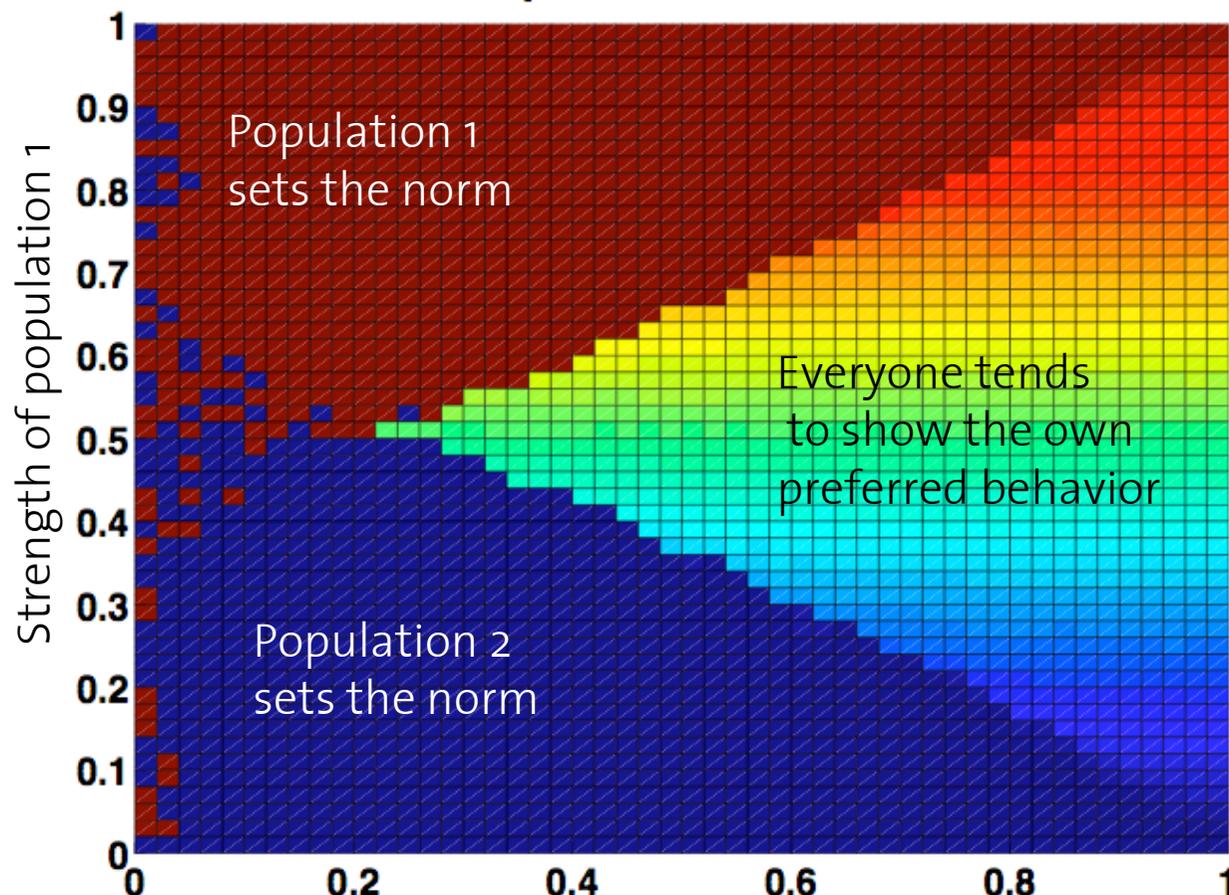
A simple model considering strategy and location changes and noise can reproduce various **stylized facts** of social systems:

1. **Individuals like to agglomerate** (form cities, groups, etc.)
2. Individuals with different behavioral strategies tend **to segregate** (--> see also Schelling)
3. **Levels of cooperation** in the prisoner's dilemma and in public goods games are **higher than expected**; they tend to break down, but may grow, if people can leave bad environments and choose more favorable ones
4. Individual **behaviors are partially determined by the social environment** they are contributing to (--> norms)
5. Social environments **persist** much longer than an average individual contributes to it (--> **social institutions**)
6. Social systems perform well by **continuous adaptation**

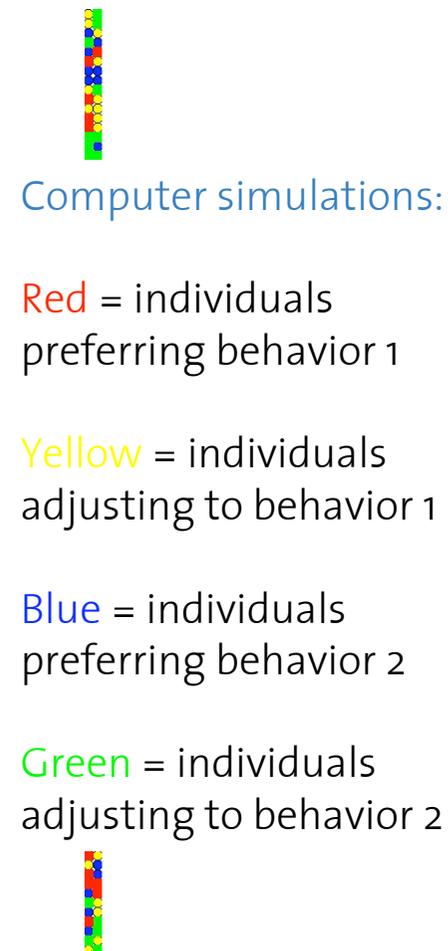
## Possible Outcomes in the Two-Population Norms Game

$\varepsilon = 0.01$ , Interaction Partner = 1,  $p_0 = p_1 = 0.5$

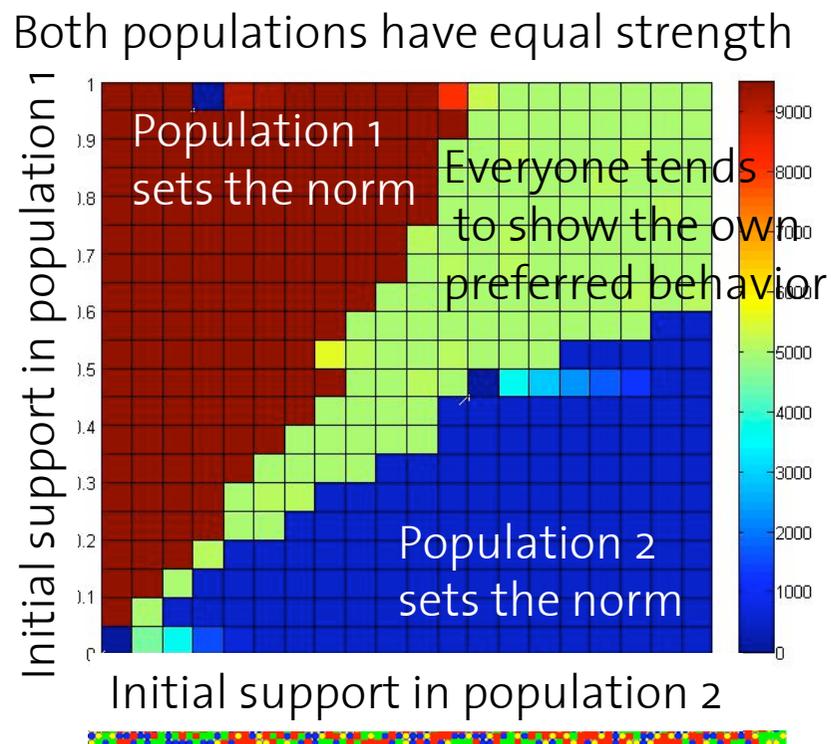
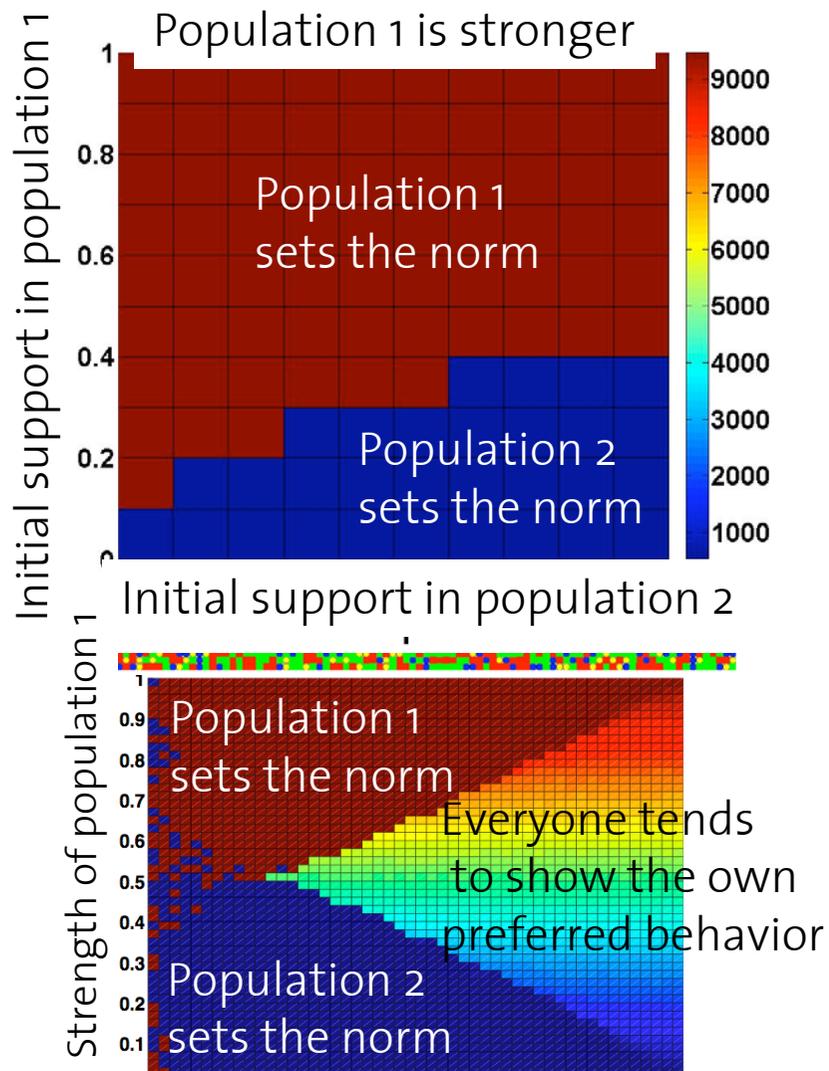
Proportional Imitation



Reward of showing preferred behavior / Reward of conforming

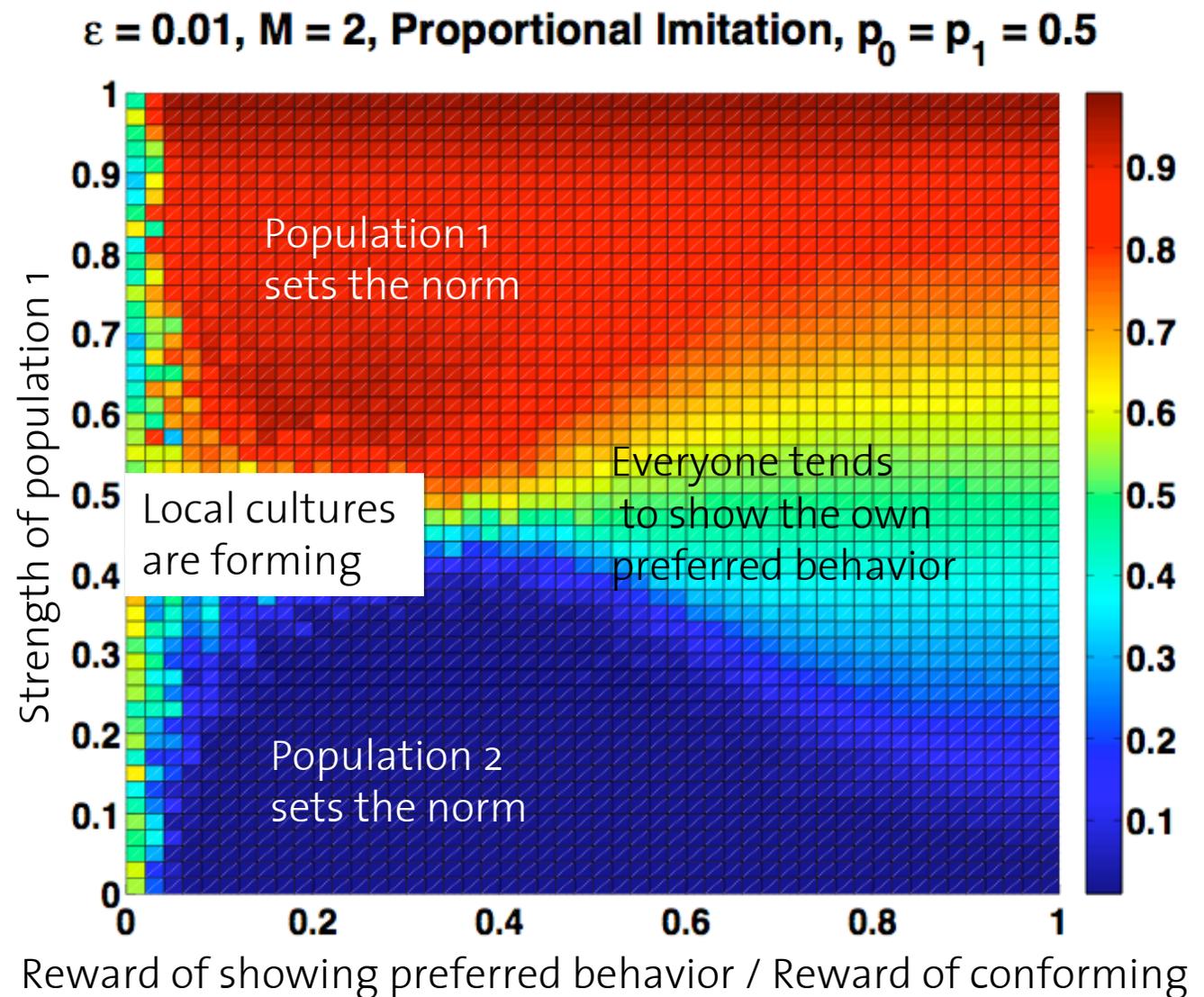
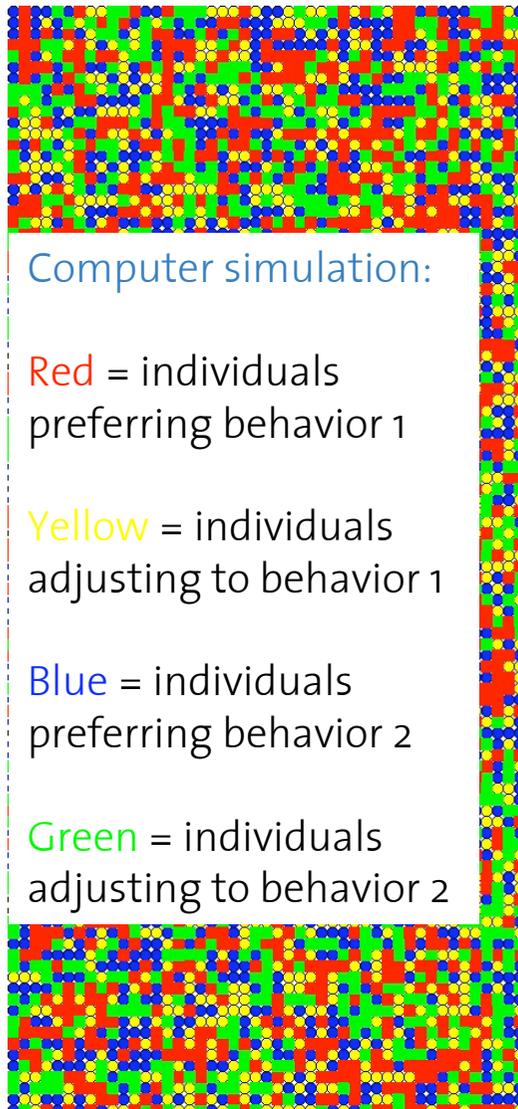


# History/Path Dependence - The Initial Condition Matters



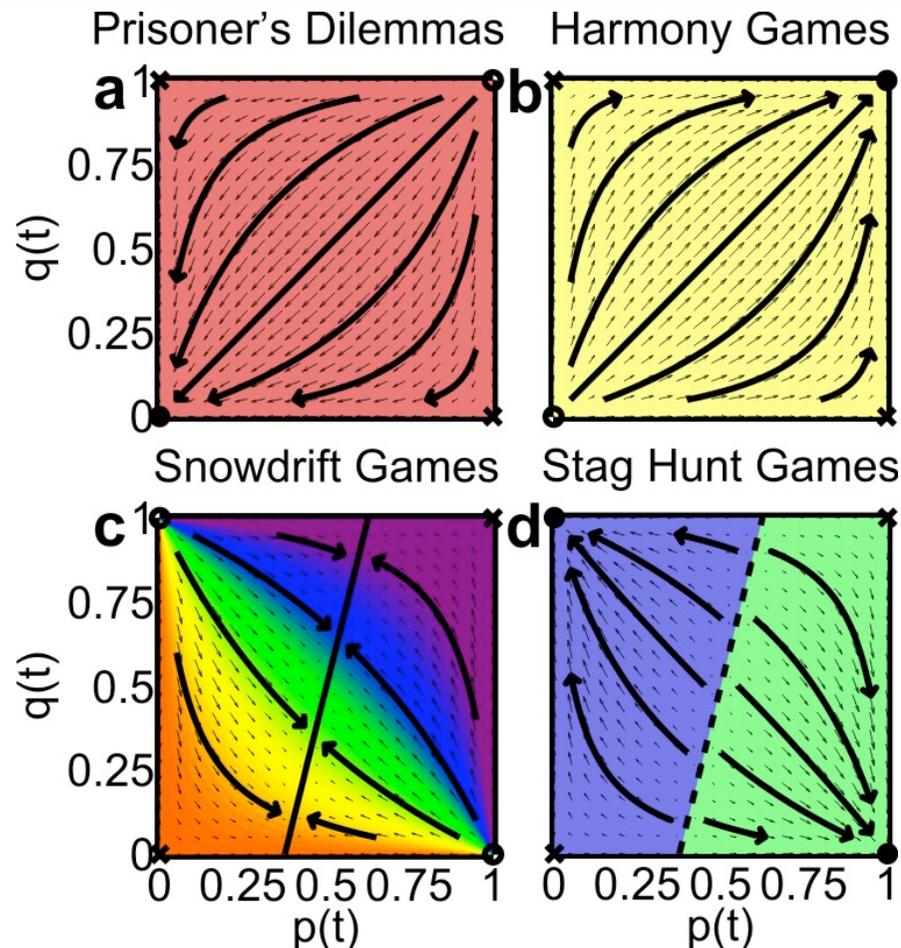
Reward of showing preferred behavior / Reward of conforming

## Possible Outcomes in the Norms Game with Local Interactions



## Two Populations with Incompatible Interests

Breakdown  
of cooperation



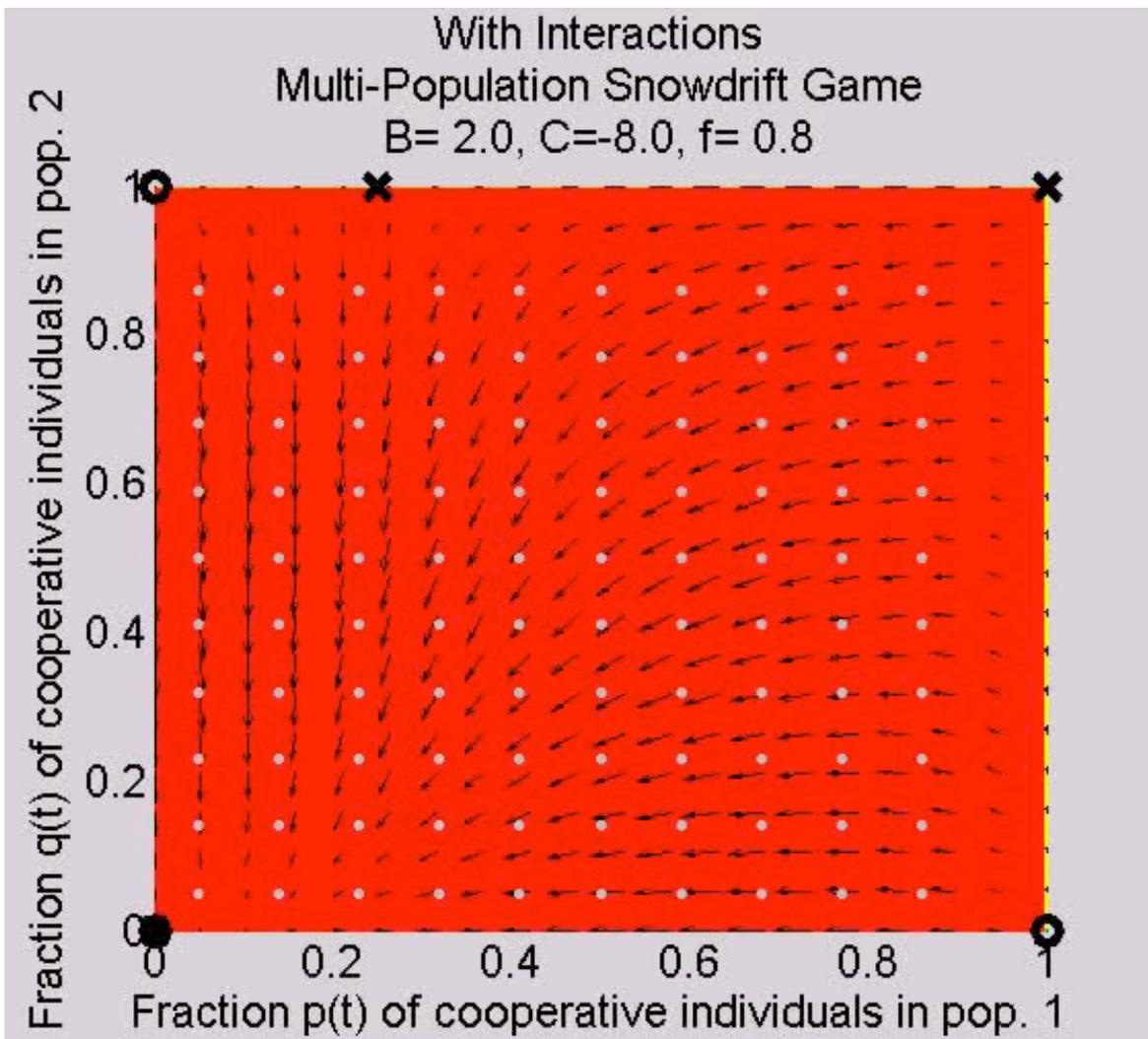
Formation of  
subcultures

Polarization

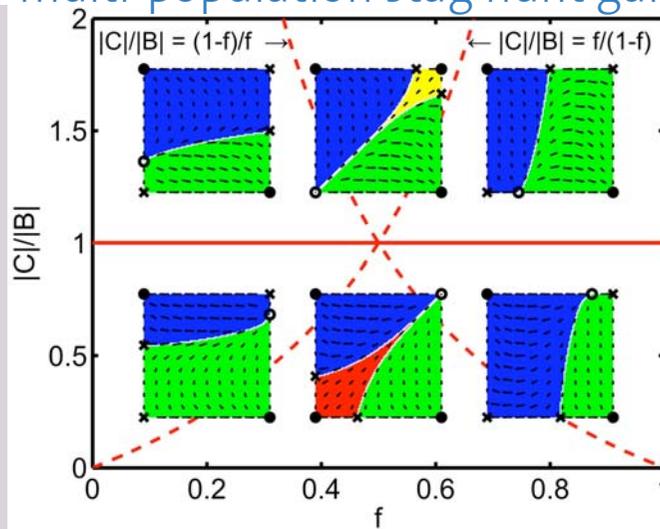
Formation of shared  
behavioral norms

Only in the stag hunt game we find that both populations tend to use the same behavioral strategy, i.e. **a behavioral norm evolves!** The norm-creating mechanism is also important for the **evolution of language.**

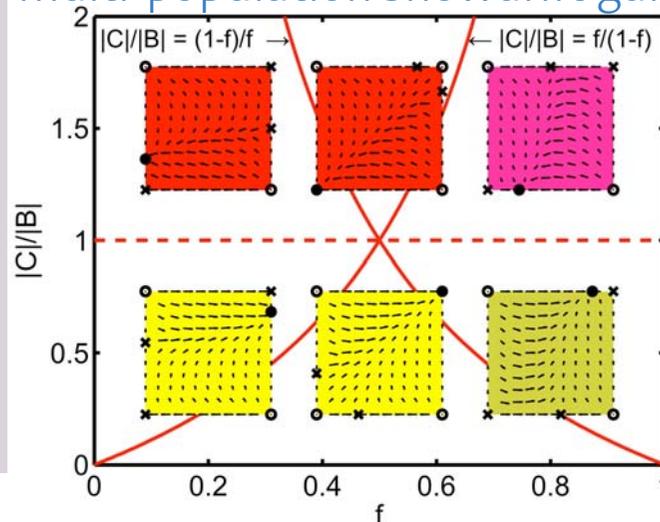
# Relevance of the Payoff Parameters and Power



multi-population stag hunt game

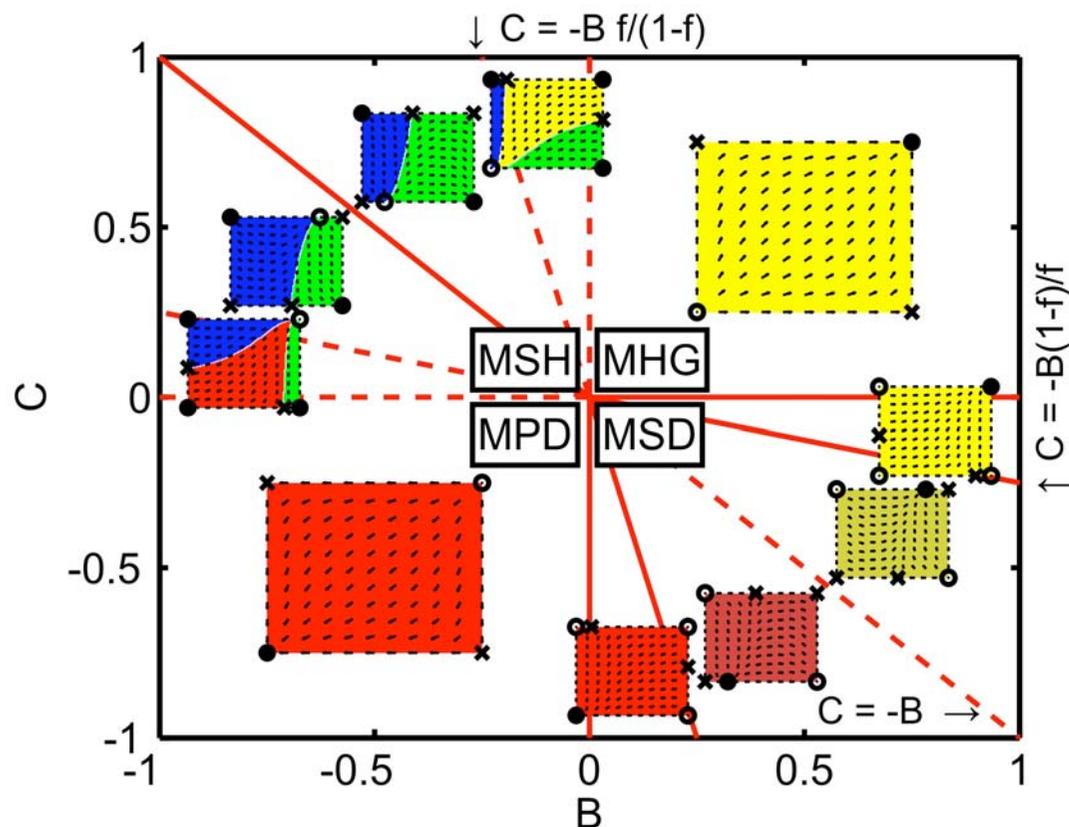


multi-population snowdrift game



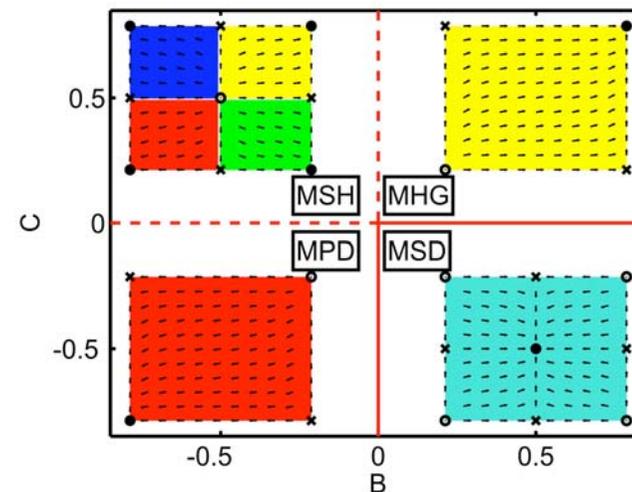
# Summary of System Dynamics in Multi-Population Games

with interactions and self-interactions

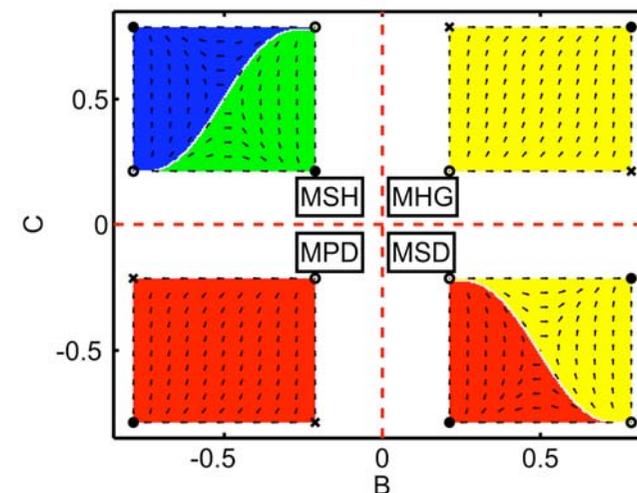


MSH = multi-population stag hunt game  
 MPD = multi-population prisoner's dilemma  
 MHG = multi-population harmony game  
 MSD = multi-population snowdrift game

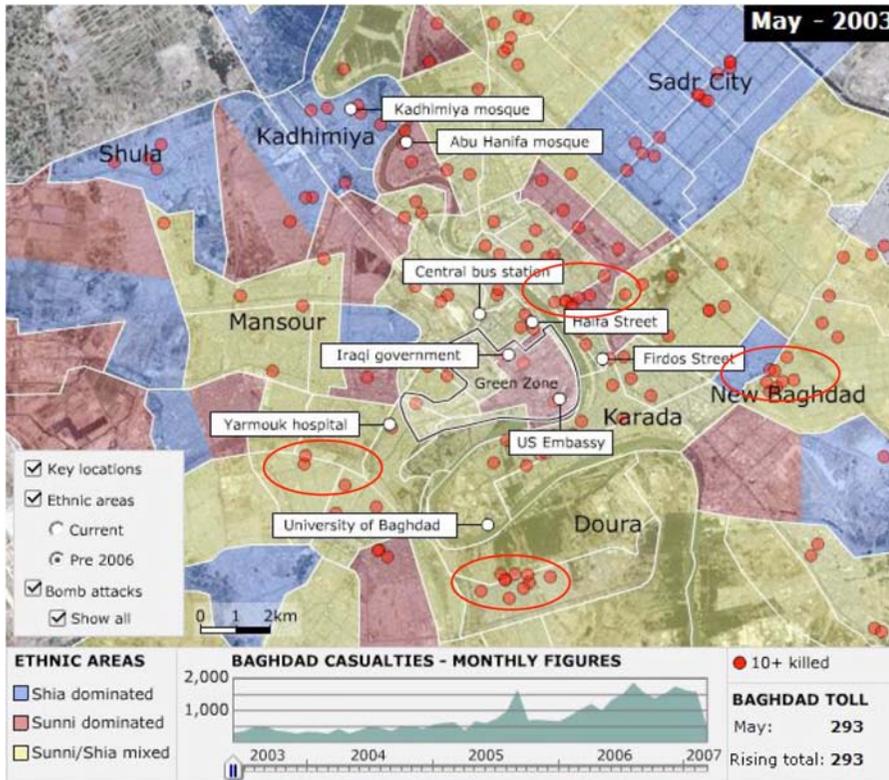
without interactions



without self-interactions



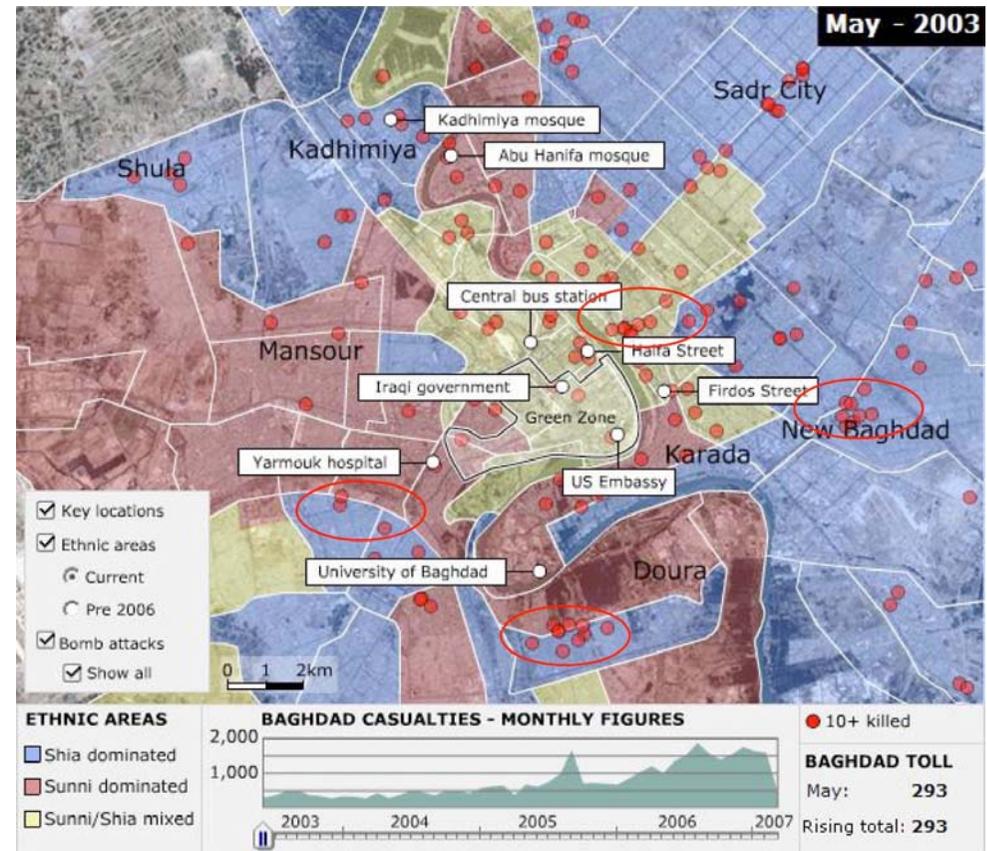
# Interrelation of Spatial Interaction, Conflict, and Migration



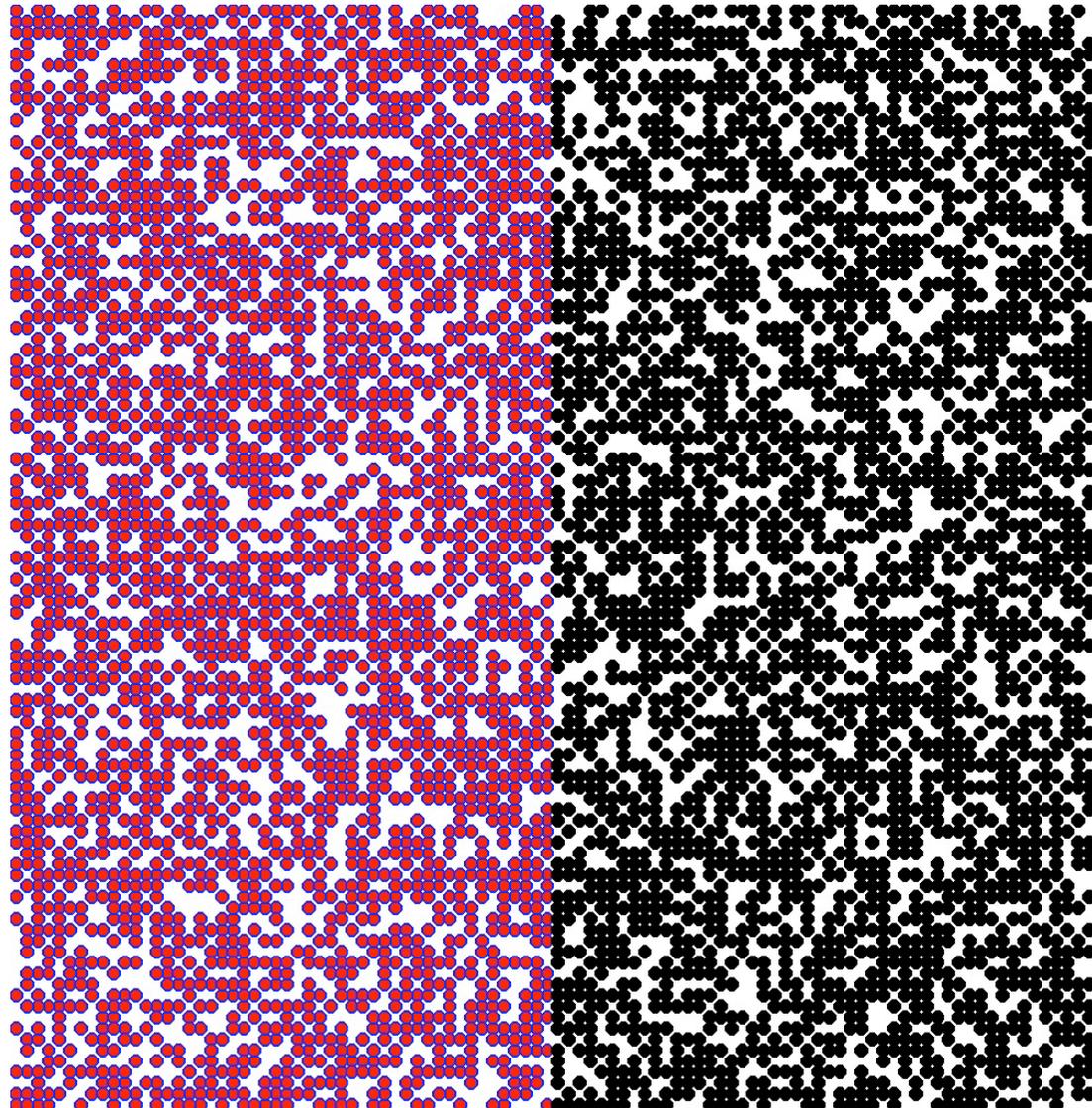
Ethnic areas and bomb attacks before 2006  
 Conflict occurs primarily at boundaries between areas with different ethnic fractions. Mixed areas shrink.

Source: BBC

Ethnic areas and bomb attacks after 2006

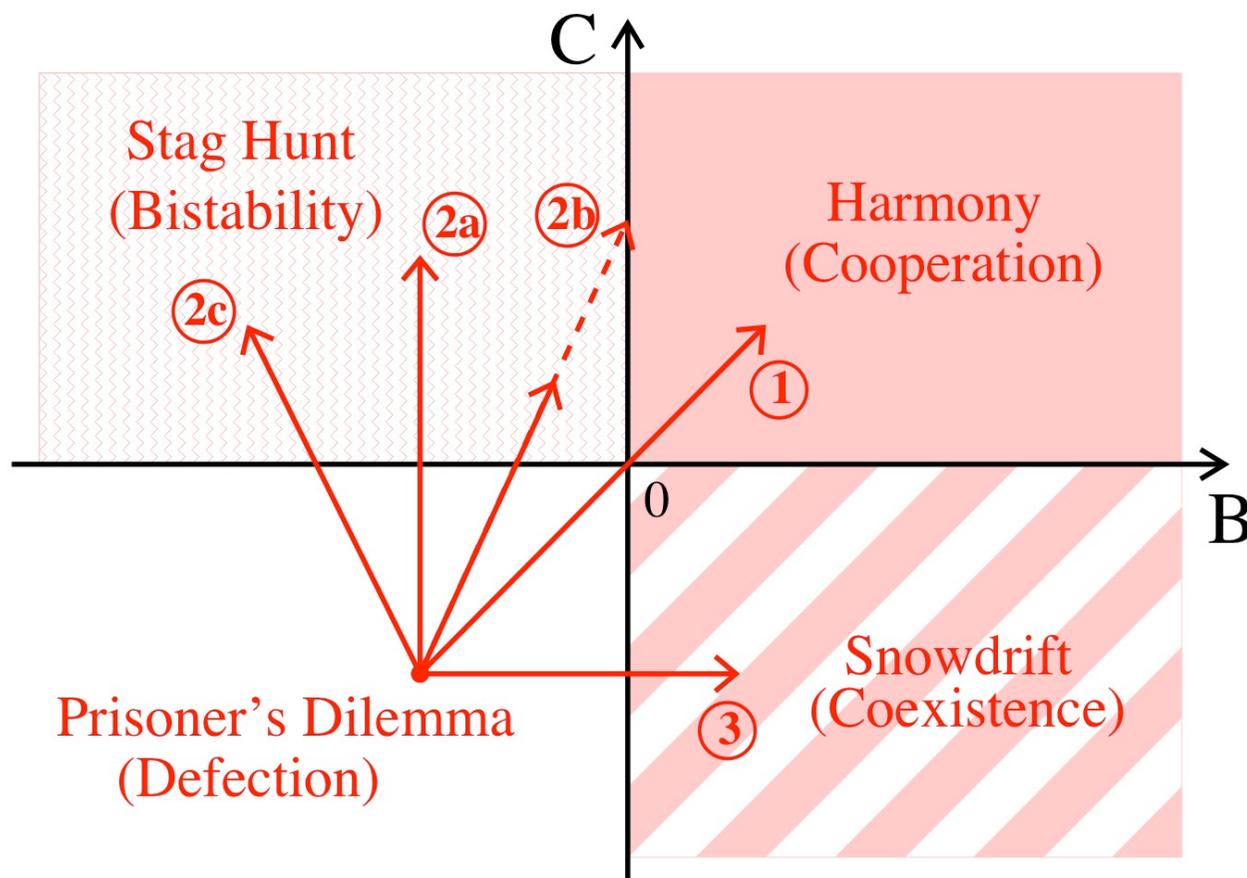


## Conflicts: Towards Simulating Conflicts



- **Cultures** refer to a set of symbols and meanings, including values and norms. They are regionally different.
- What may happen, if **two populations** with different, partially incompatible cultures start to **mix** (if we allow for migration)?
- **Unilateral adaptation, mutual adaptation, conflict, segregation**, or a combination of them?

## How to Transform the Prisoner's Dilemma into Other Games



Route 1: Kin selection, 3: Network interactions (don't support norms)  
2a: Direct reciprocity, 2b: Indirect reciprocity, 2c: Punishment (support norms)

## Summary, Discussion and Outlook

- Simple models can produce complex behavior and promise to gain surprisingly interesting insights into the mechanisms underlying socio-economic systems
- Linear models do not allow to explain emergent self-organization phenomena
- The representative agent (mean field) approach is misleading
- Considering time-dependence, spatial interactions, and heterogeneity lead to different conclusions regarding the behavior of socio-economic systems
- Puzzles such as the occurrence of cooperation among selfish individuals (the victory of cooperators over free-riders) or the establishment of costly punishment (or the disappearance of second-order free-riders) are naturally resolved
- Mobility is essential for the co-evolution of social environment and social behavior
- It seems possible to formulate a unified model describing (1) the breakdown of cooperation, (2) the coexistence of different behaviors (subcultures), (3) the evolution of commonly shared behaviors (norms), and (4) the occurrence of social polarization or of revolutions.
- Globalization seems to endanger social cooperation. Are we on the way to a punishment society or to a reputation society?

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# Thank you for your interest!

## Any questions?

