

**Evolution of Behavior in  
the Repeated Prisoner's Dilemma.  
a Simulation**

# KEYWORDS

- **simulated population**
- **repeated game: Prisoner's Dilemma**
- **evolution: what kinds of strategies survive**

# THE GAME

- 2 players
- each can have 2 actions {Cooperate, Defect}

PD	Cooperate	Defect
Cooperate	3,3	0,4
Defect	4,0	1,1

# THE GAME

<b>P1\P2</b>	<b>Cooperate</b>	<b>Defect</b>
<b>Cooperate</b>	<b>3,3</b>	<b>0,4</b>
<b>Defect</b>	<b>4,0</b>	<b>1,1</b>

# THE GAME

PD	Cooperate	Defect
Cooperate	3	0
Defect	4	1

# THE GAME

**PD**

**Cooperate**

**Cooperate**

**3**

**Defect**

**4**

# THE GAME

PD	Cooperate
Cooperate	3
Defect	4 *

*\* required assumption: rationality in a weak sense  
player prefers higher payoff (utility)*

# THE GAME

**PD**

**Defect**

**Cooperate**

**0**

**Defect**

**1**



# THE GAME

**PD**

**Defect**

**Cooperate**

**0**

**Defect**

**1 \***

# THE GAME

PD	Cooperate	Defect
<del>Cooperate</del>	3,3	0,4
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# **COOPERATIVE BEHAVIOR**

**-> conflict between self interest and social efficiency**

**given rationality in the least sense**

# ONESHOT VS REPEATED INTERACTION

**oneshot:**

- **strangers**
- **anonymous matching**

**repeated:**

- **partners, colleagues, worker-employer**
- **people you have enough data history to form expectation on how they would behave in a particular situation**

# STRATEGY SET

**oneshot:**

**- 2 possible strategies: C D**

**repeated:**

**- grows exponentially with number of rounds**

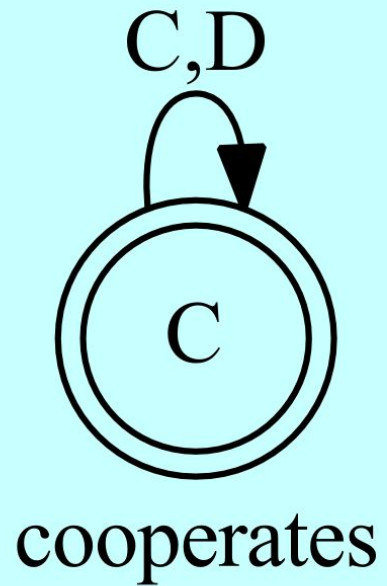
**- examples: to play for 10 rounds:**

**strategy 1: C C D D D ...**

**strategy 2: C C C C C ...**

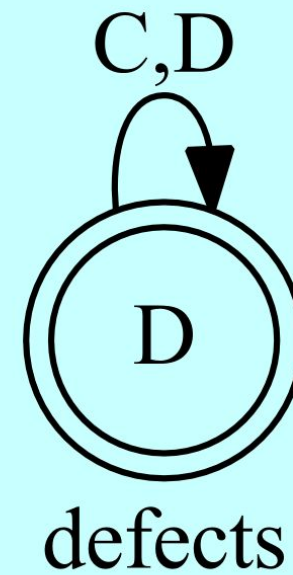
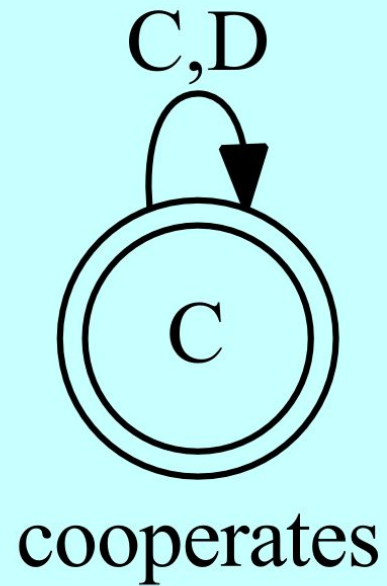
**strategy 3: D D C C C ...**

# STRATEGY REPRESENTATION: REPEATED GAME

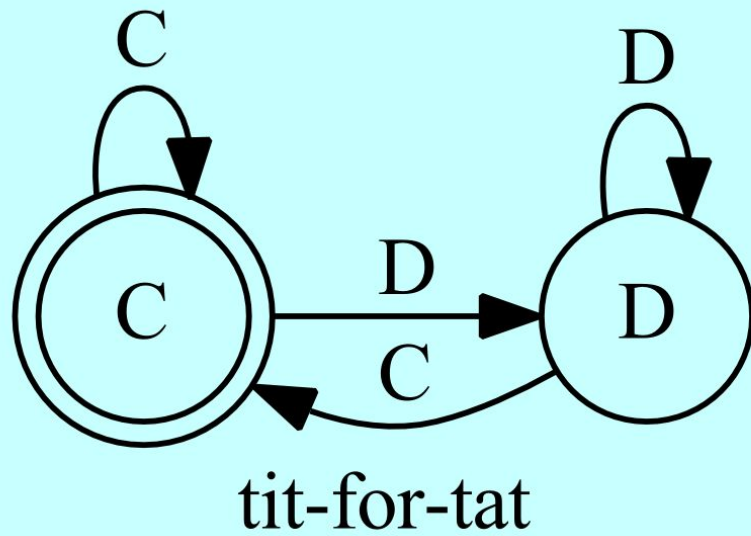




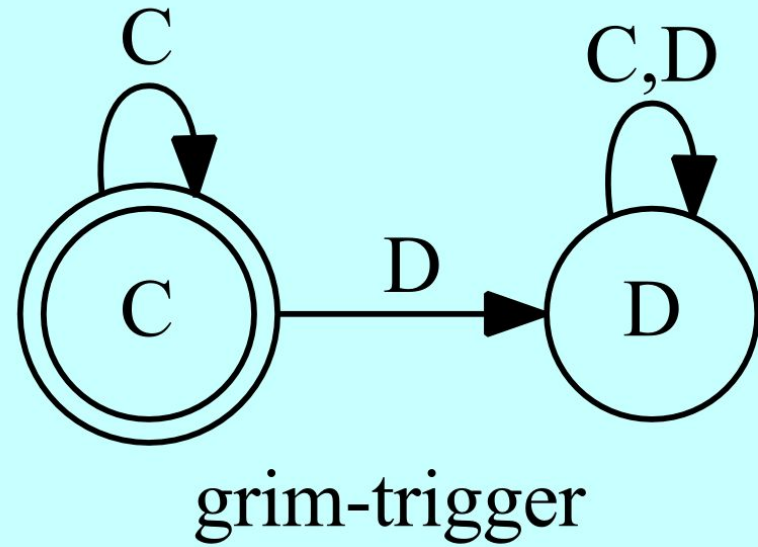
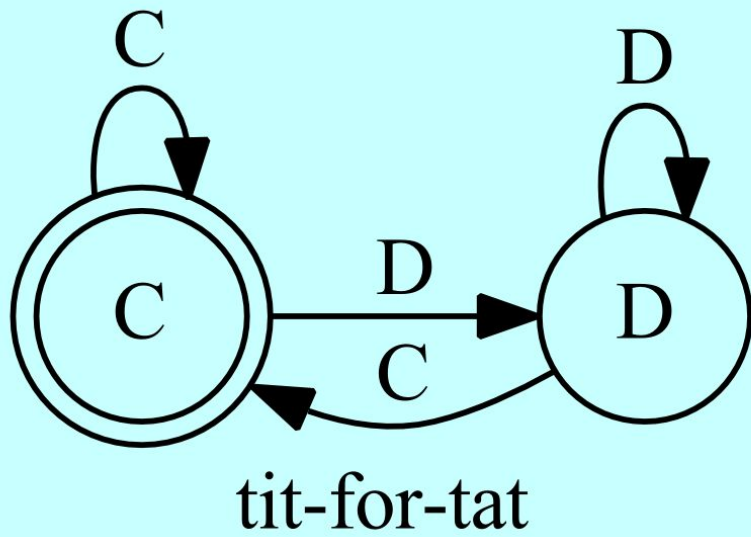
# STRATEGY REPRESENTATION: REPEATED GAME



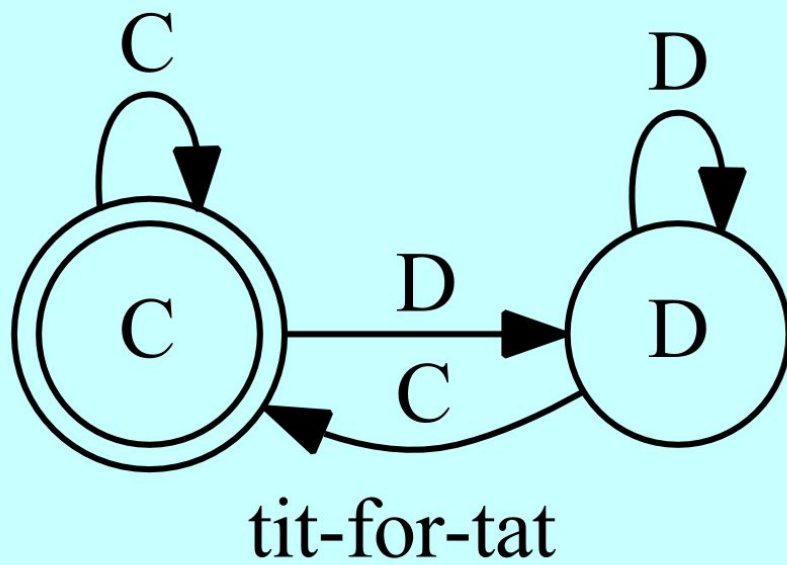
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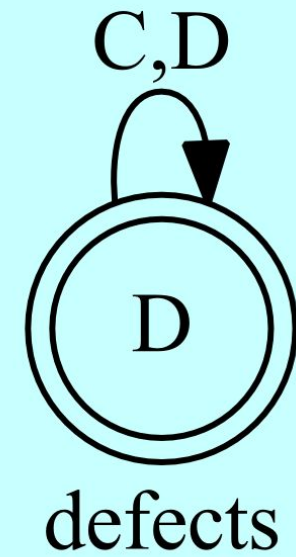
# STRATEGY REPRESENTATION: REPEATED GAME



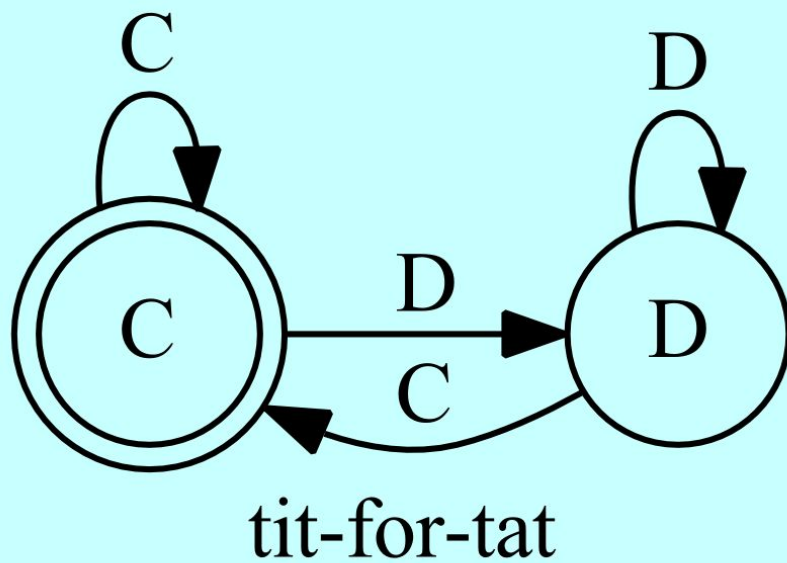
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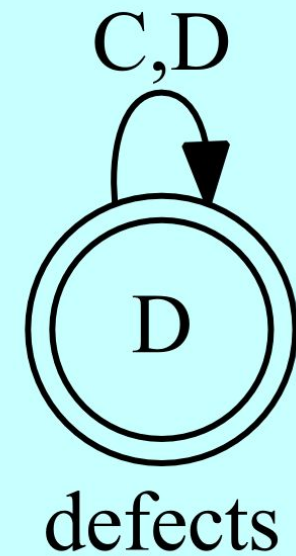
0 4



# STRATEGY REPRESENTATION: REPEATED GAME



0	4
1	1
1	1
1	1



# AUTOMATON STRUCTURE

(automaton head

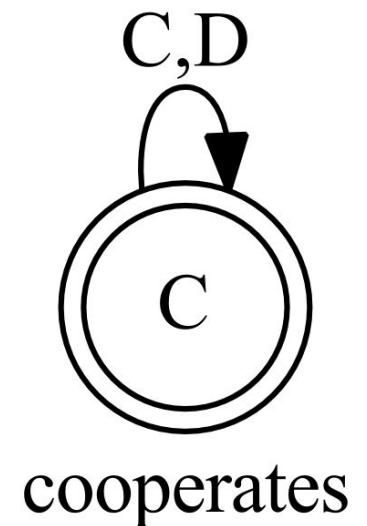
'INITIAL	
'CURRENT	
'PAYOFF	

body)

0	(state action dispatch)	<table border="1"><tr><td>'D</td><td></td></tr><tr><td>'C</td><td></td></tr></table>	'D		'C	
'D						
'C						
1						
2						
...						

(automaton

```
'#hash((INITIAL . 0) (PAYOFF . 0) (CURRENT . 0))  
(hash 0 (state 'C '#hash((D . 0) (C . 0))))
```



# **SIMULATION**

- imagine a world with many slots**
- we populate it with N agents**
- the agents adopt the strategies and play**

**agent:**

- machine/automaton**
- do agency: given a contract,  
they play by the book until terminate**

# **EVOLUTION**

**evolution = selection + mutation**

**- selection: survival of the fittest**

**(at the expense of the poor doers)**

**- mutation: is to keep adding new strategies**

**into the selection pool**

**to mimic that, we run a simulation of many cycles.**

**a typical cycle has 3 phase:**

**- matching phase**

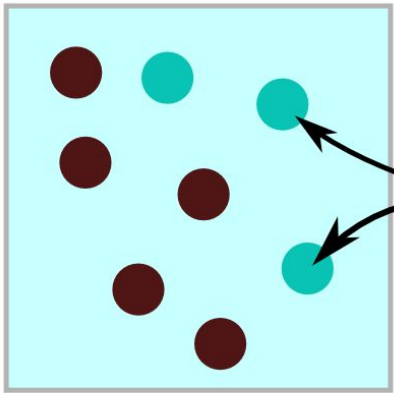
**- learning phase**

**- mutation phase**



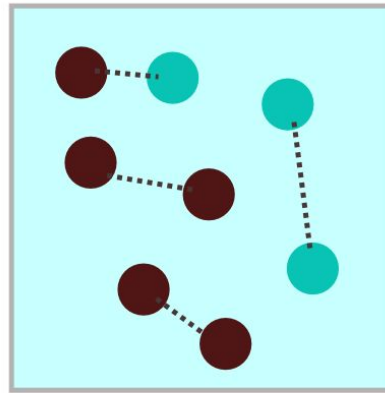
# SIMULATION CYCLE: MATCHING PHASE

population

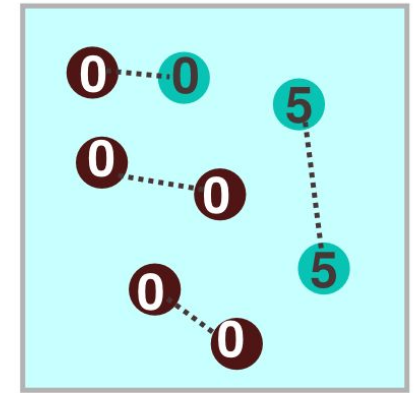


agent

random pair-match  
to play PD repeatedly



payoff sequence  
-> fitness\*



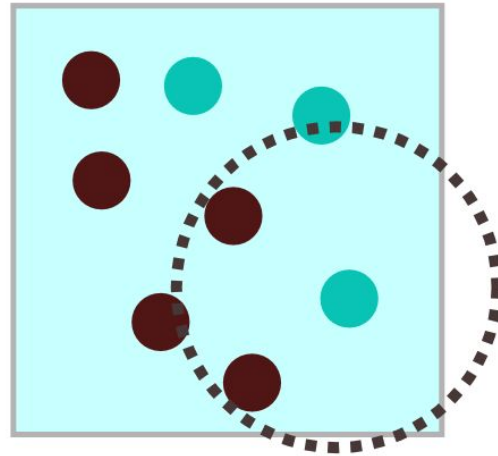
# SIMULATION CYCLE: LEARNING PHASE

fitness

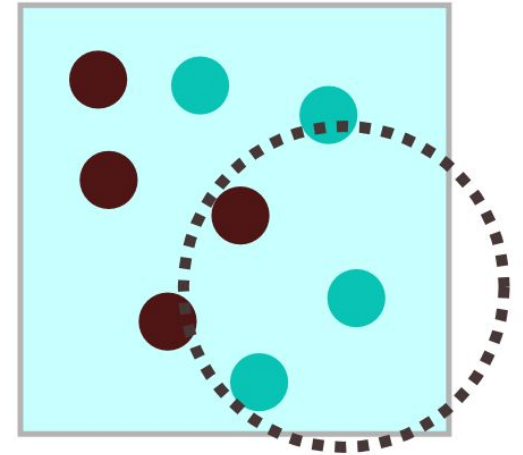
5  
5  
0  
0  
0  
0  
0  
0



learning\*

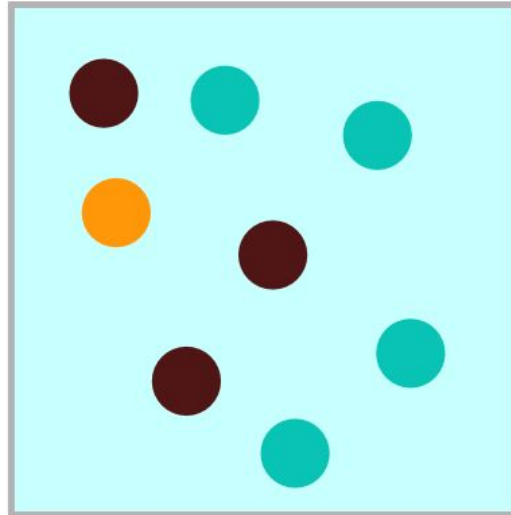


learning

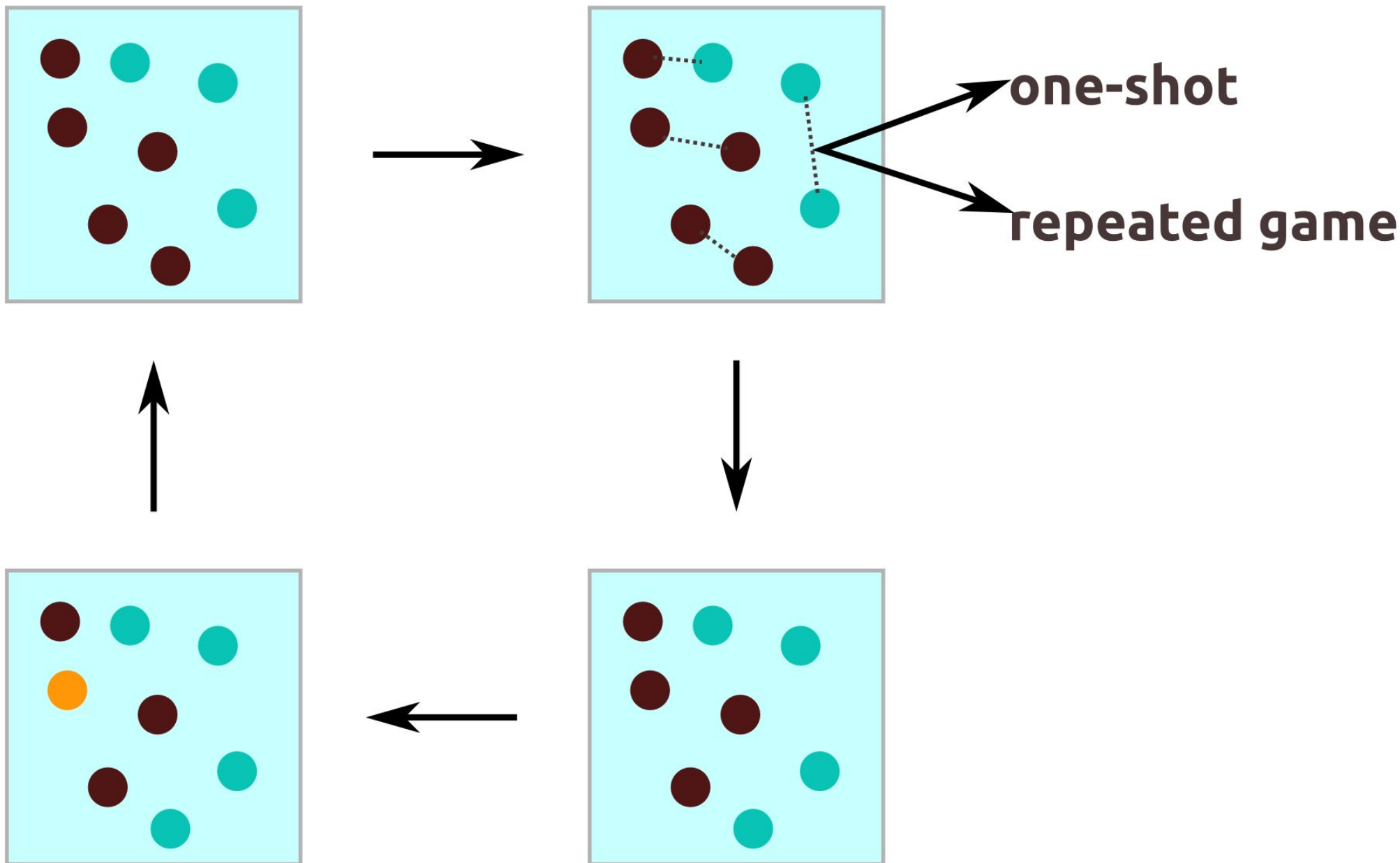


# SIMULATION CYCLE: MUTATION PHASE

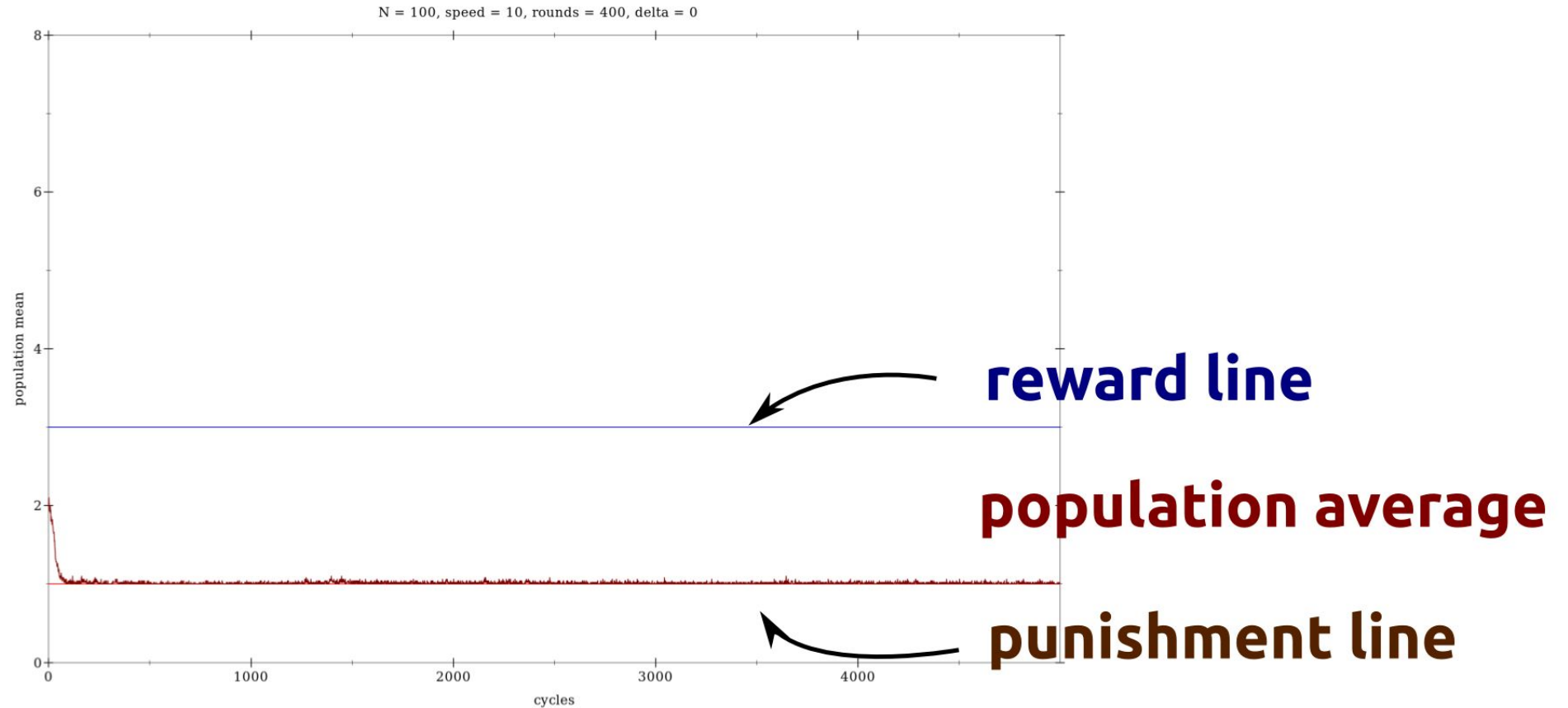
mutation\*



# SIMULATION CYCLE

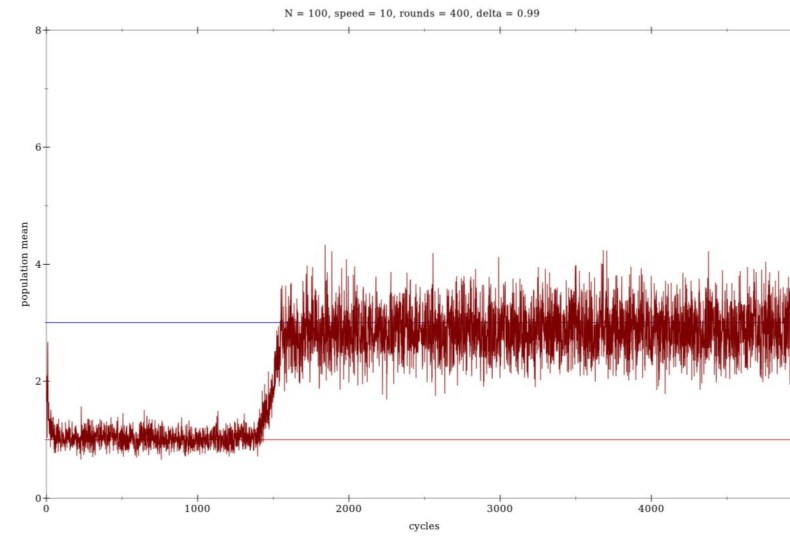
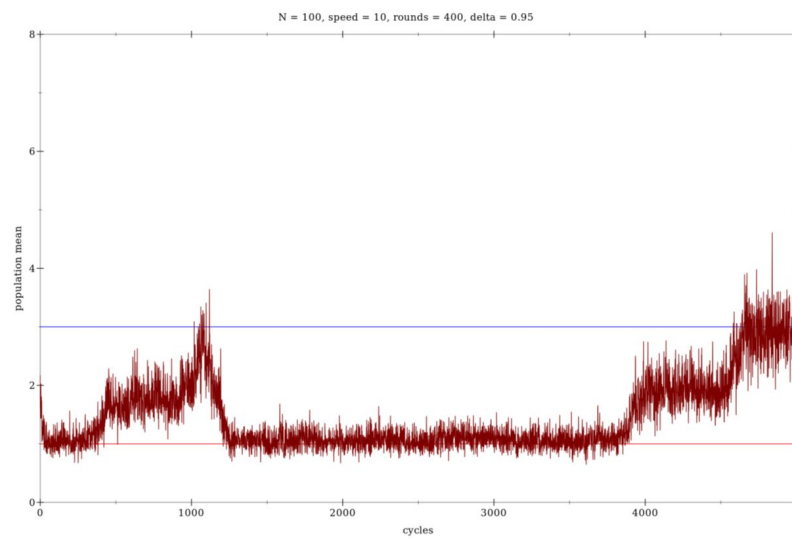
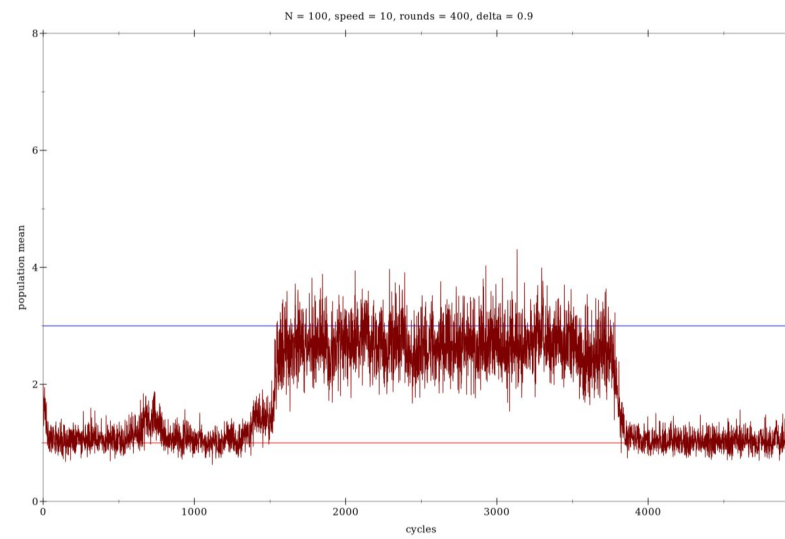
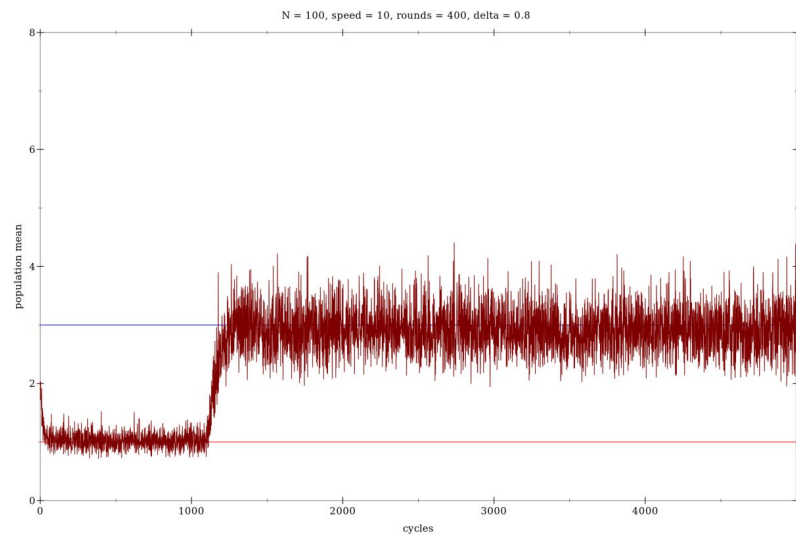


# SIMULATION RESULT: ONESHOT GAME

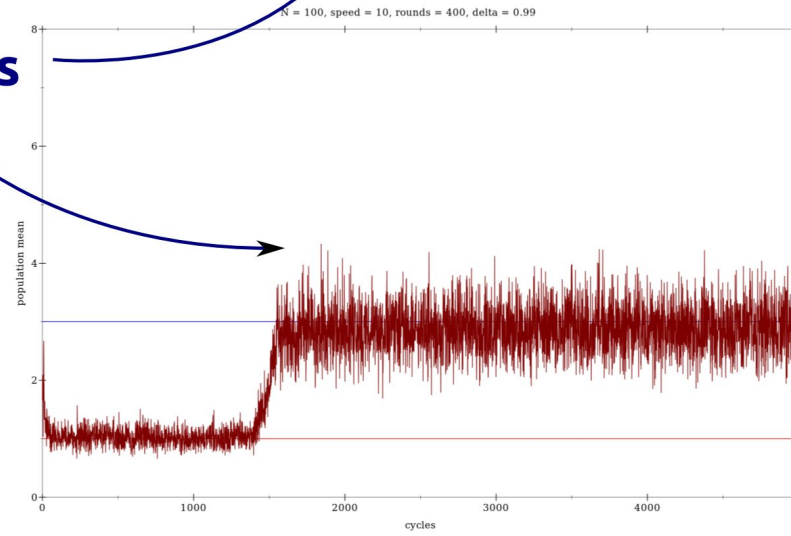
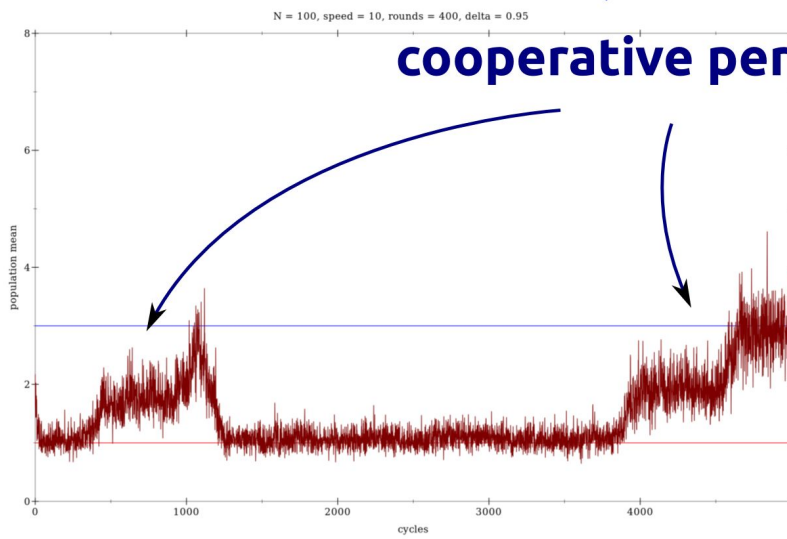
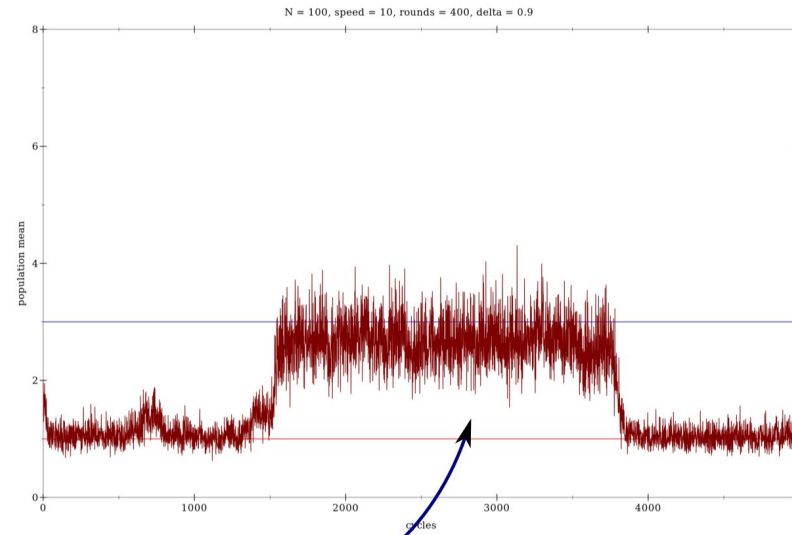
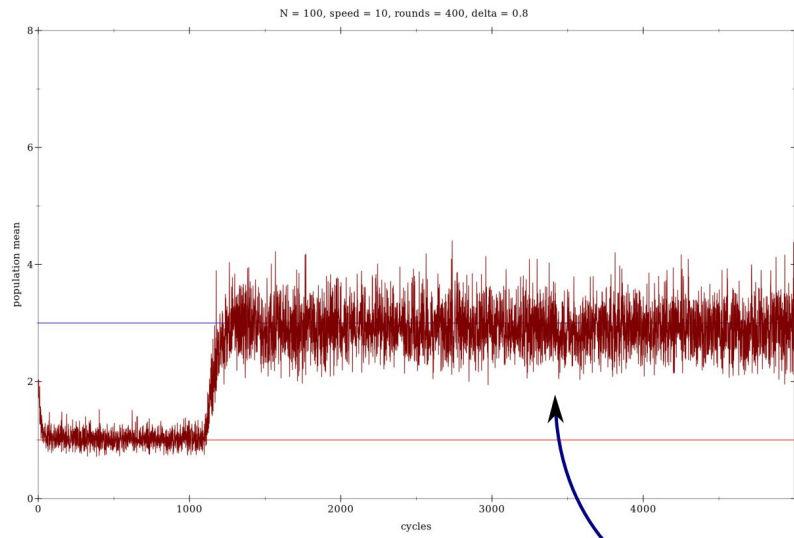


**everybody defects everybody**

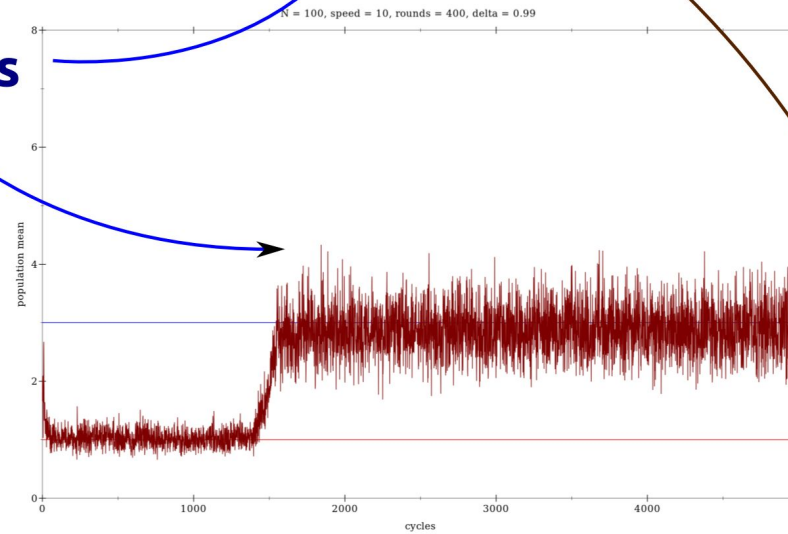
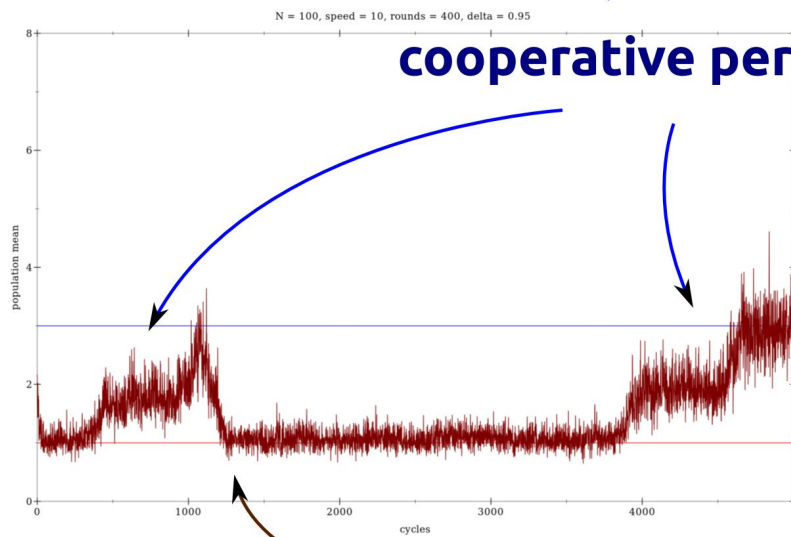
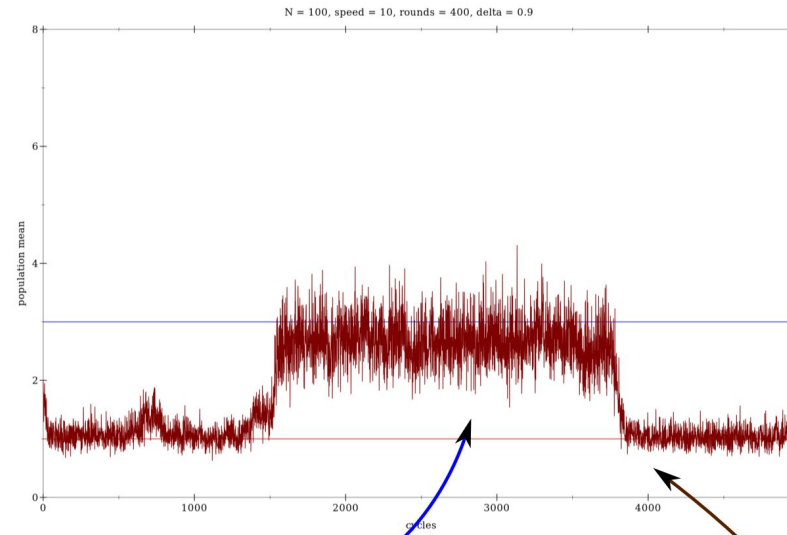
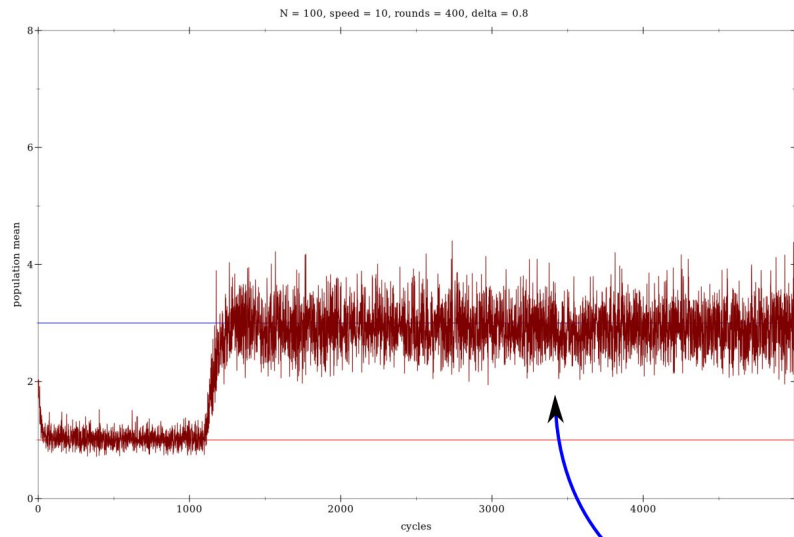
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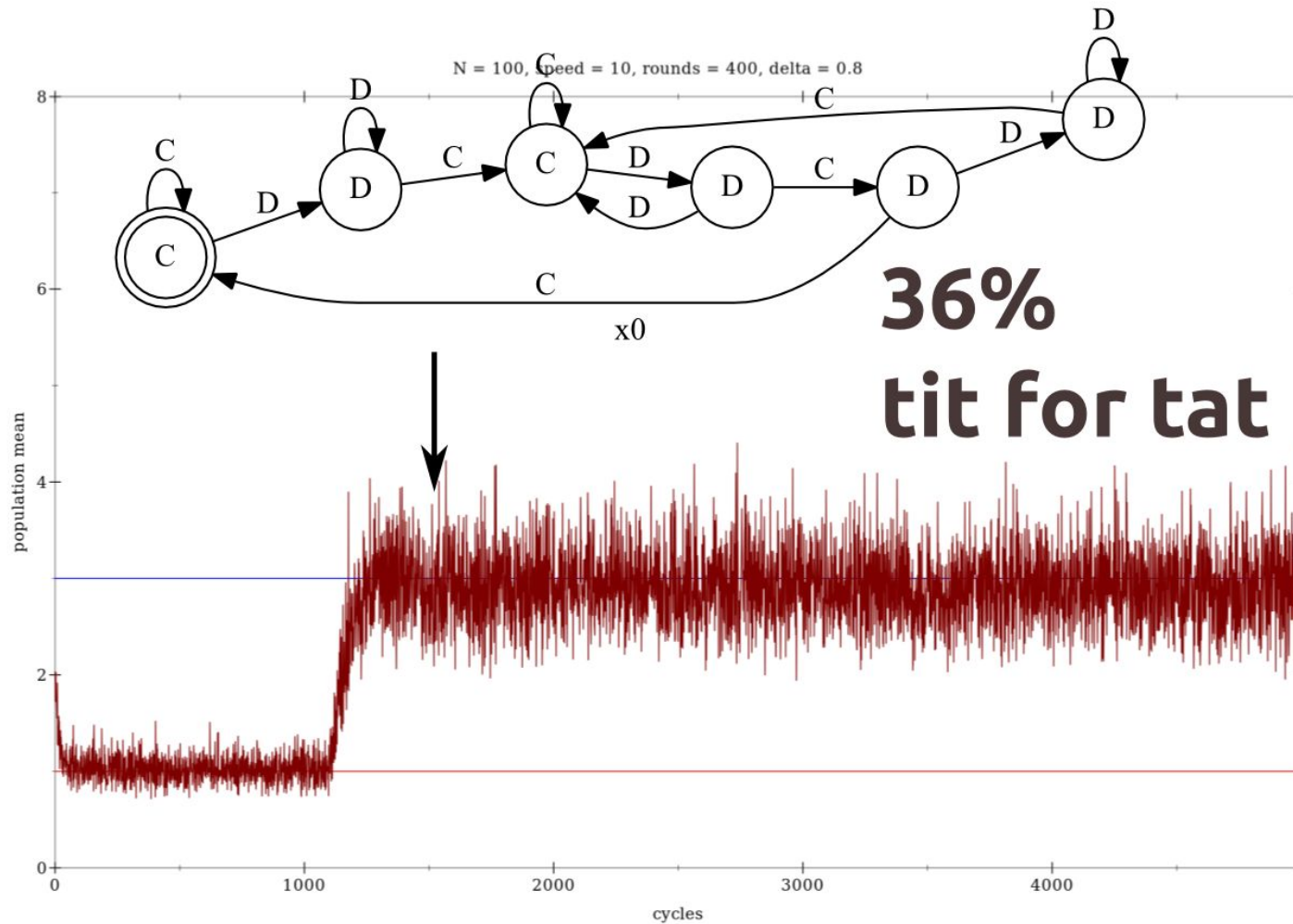
# SIMULATION RESULT: REPEATED GAME



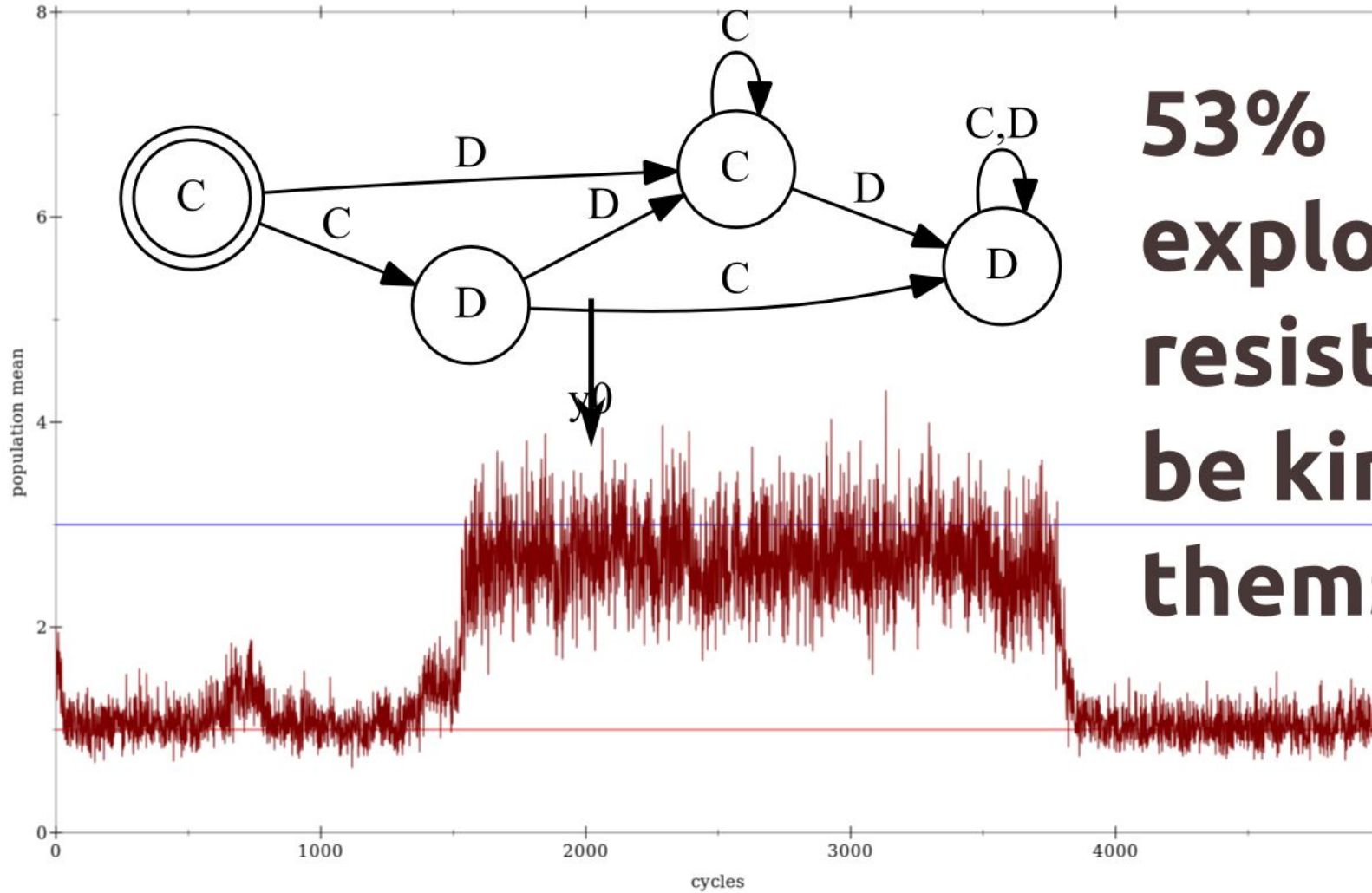
doesn't mean that cooperation is for sure



# WHAT HAPPENS IN THESE PERIODS? what strategies sustain the cooperation?

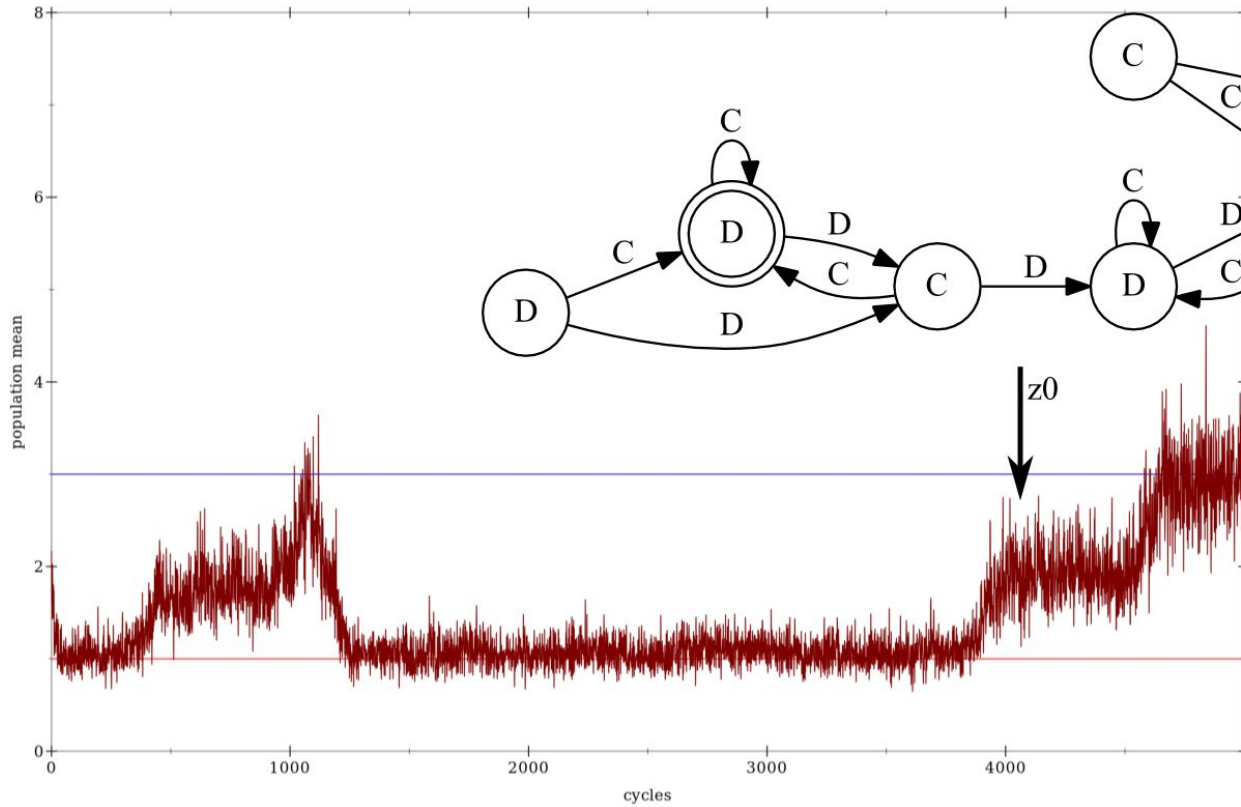


N = 100, speed = 10, rounds = 400, delta = 0.9

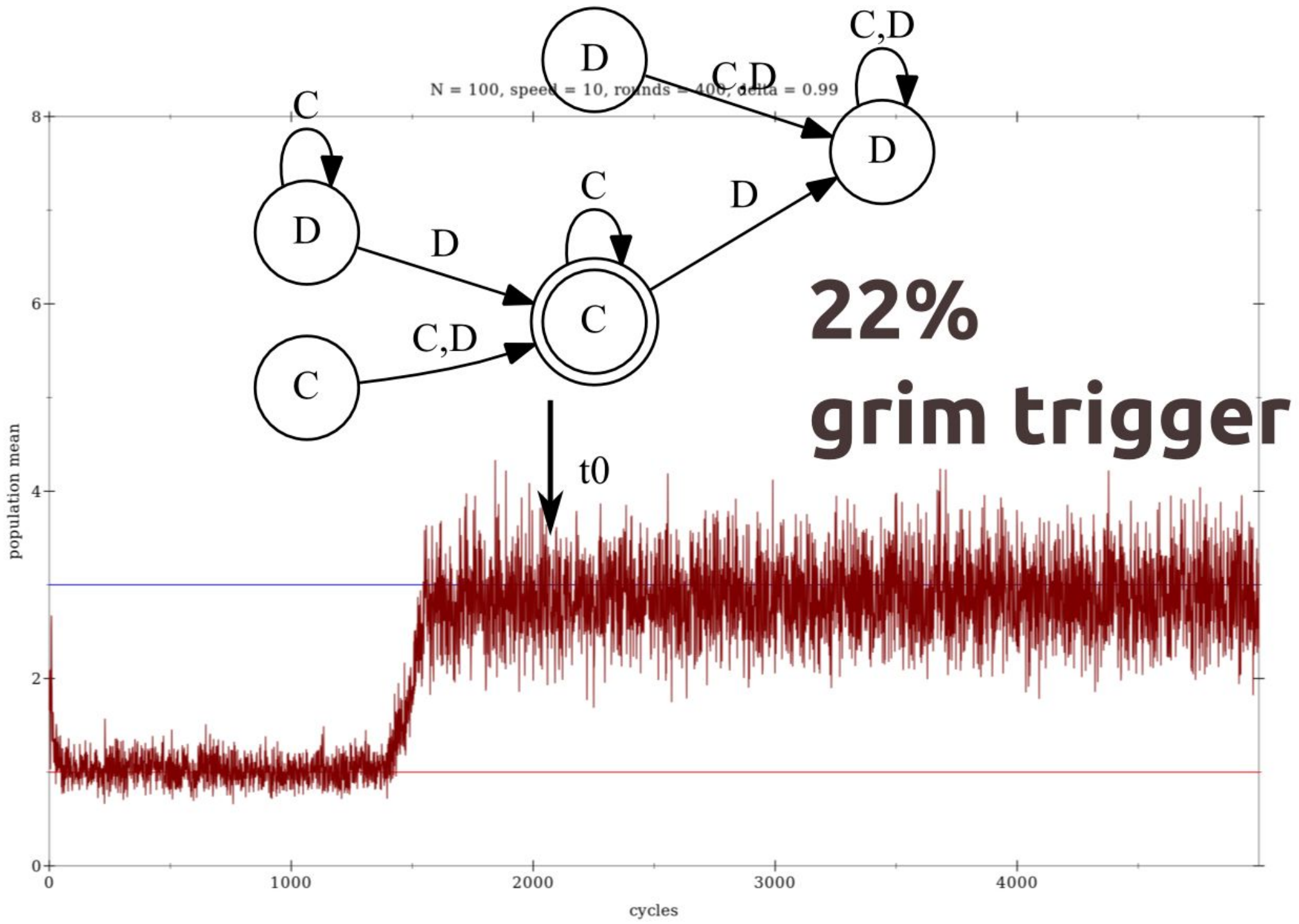


**53%**  
**exploit C**  
**resist D**  
**be kind among**  
**themselves**

N = 100, speed = 10, rounds = 400, delta = 0.95



**42%**  
**exploit C**  
**resist D**  
**alternate**  
**between themselves**



## CONCLUDING REMARKS (...)

from simulations like these, we can suggest an interpretation that says **sufficiently long horizon of repeated interaction stabilises cooperation** (in the Prisoner's Dilemma).

In other words, we can say that cooperative behavior is supported on *a priori* ground (it is rational) and it leads to the the enjoyable outcome of better social welfare.

## ACKNOWLEDGEMENT

Luciano Andreozzi (*theoretical advision*)  
Matthijs van Veelen (*influence on this project*)  
Budo Kai Punto Zero Trento  
& many others making this happen

Matthias Felleisen  
Vincent St Amour  
Hoang Minh Thang

*everything good in  
my Racket code*

RACKET code is on my github: [ayaderaghul/fsm-pd2](https://github.com/ayaderaghul/fsm-pd2)  
I blog at [ayaderaghul.github.io](https://ayaderaghul.github.io)

## Q&A

please tell me if you feel something deserved to be said  
or send your thoughts to [nguyenlinhchi09@gmail.com](mailto:nguyenlinhchi09@gmail.com)