The Struggle of the Commons

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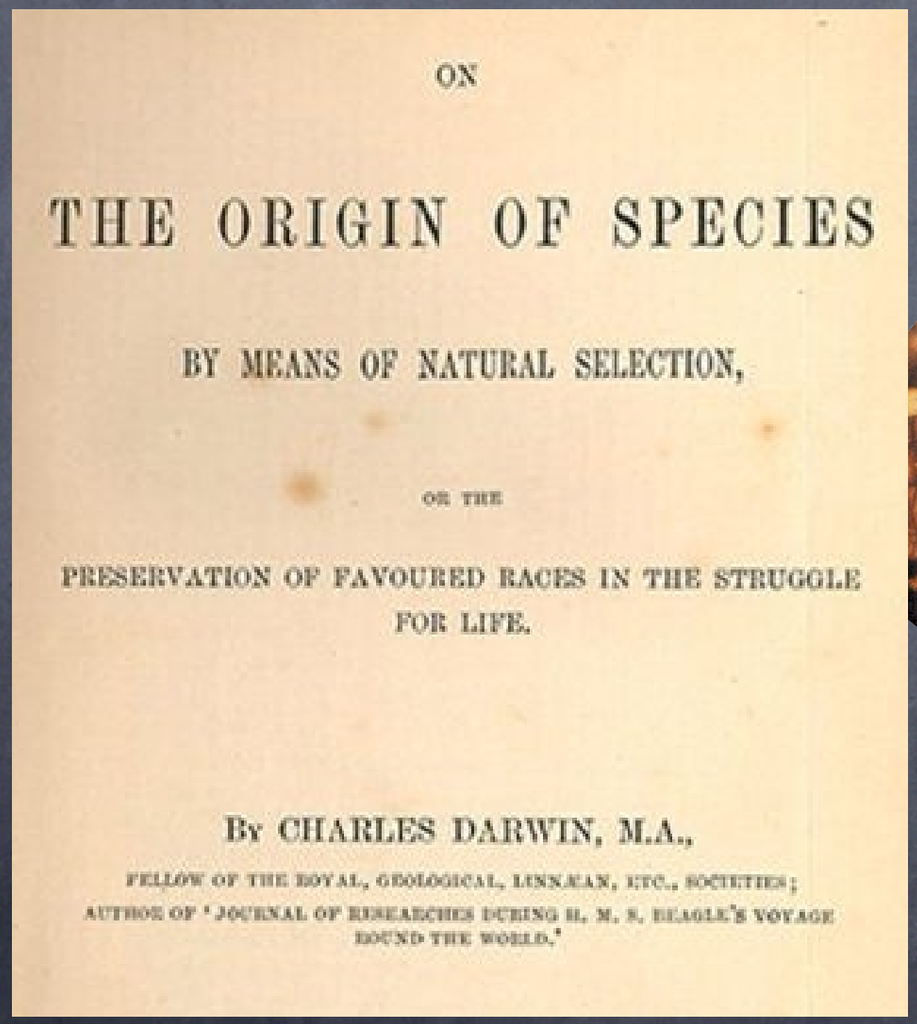
A fundamental question

- How to balance the particular behavior of the individual ...
- ... with the optimal outcome of the group?



ON

THE ORIGIN OF SPECIES

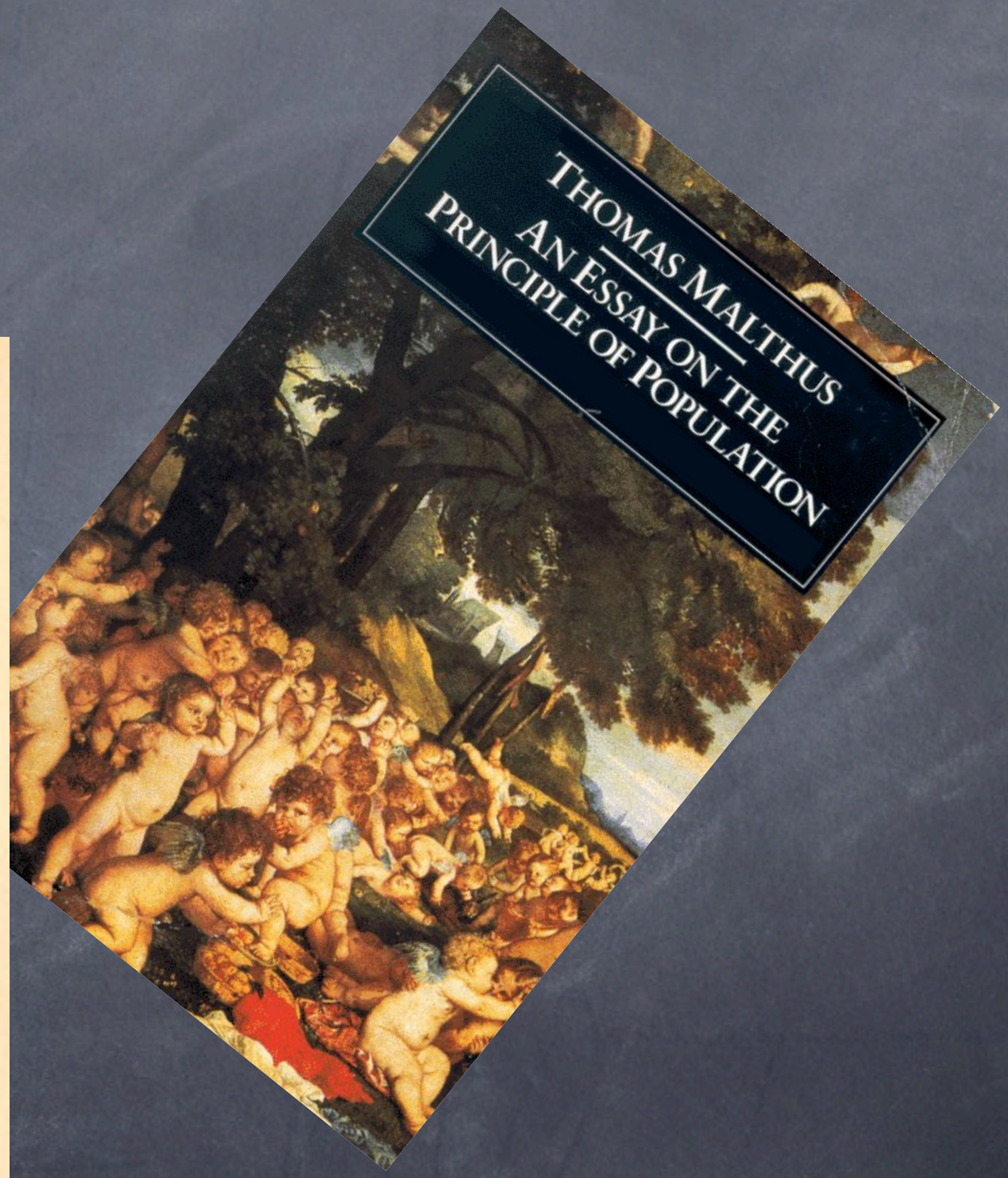
BY MEANS OF NATURAL SELECTION,

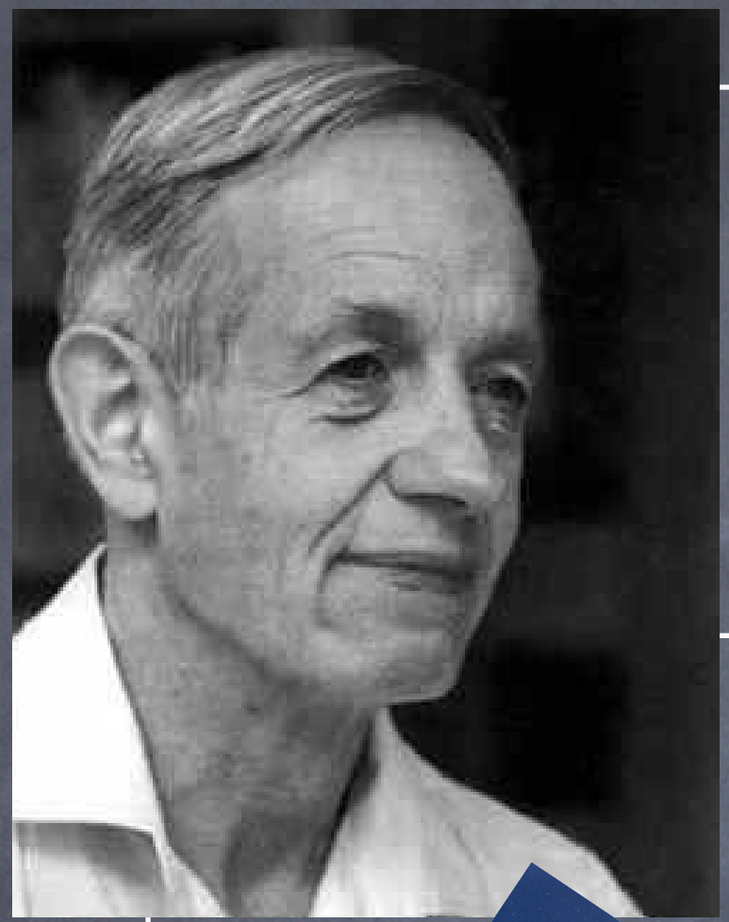
OR THE

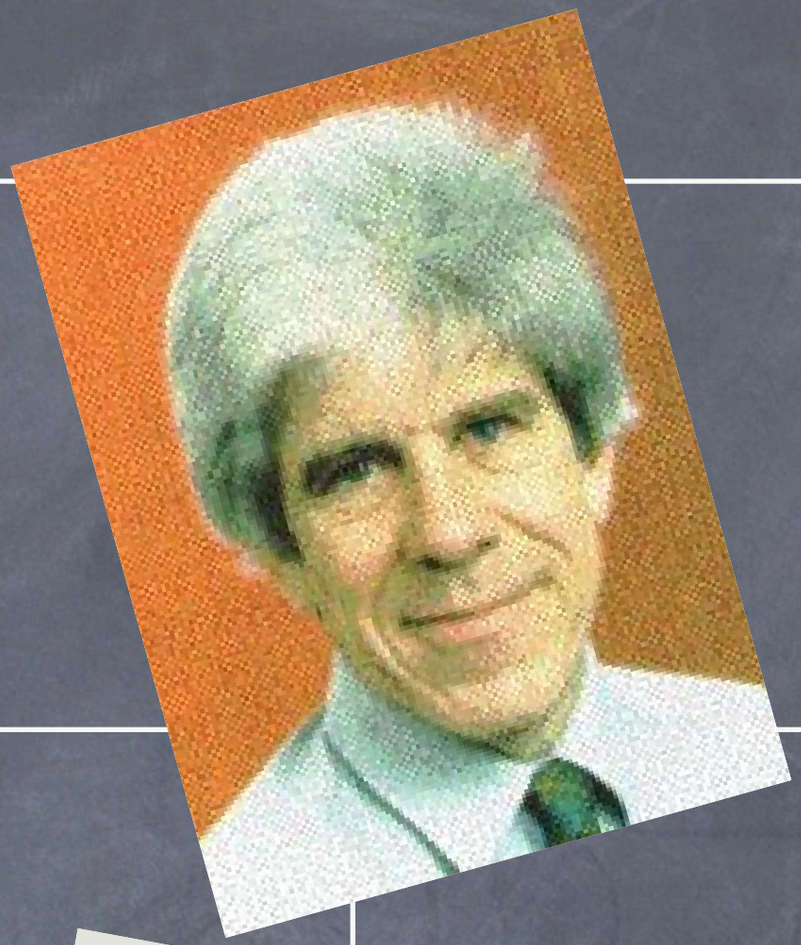
PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

BY CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'



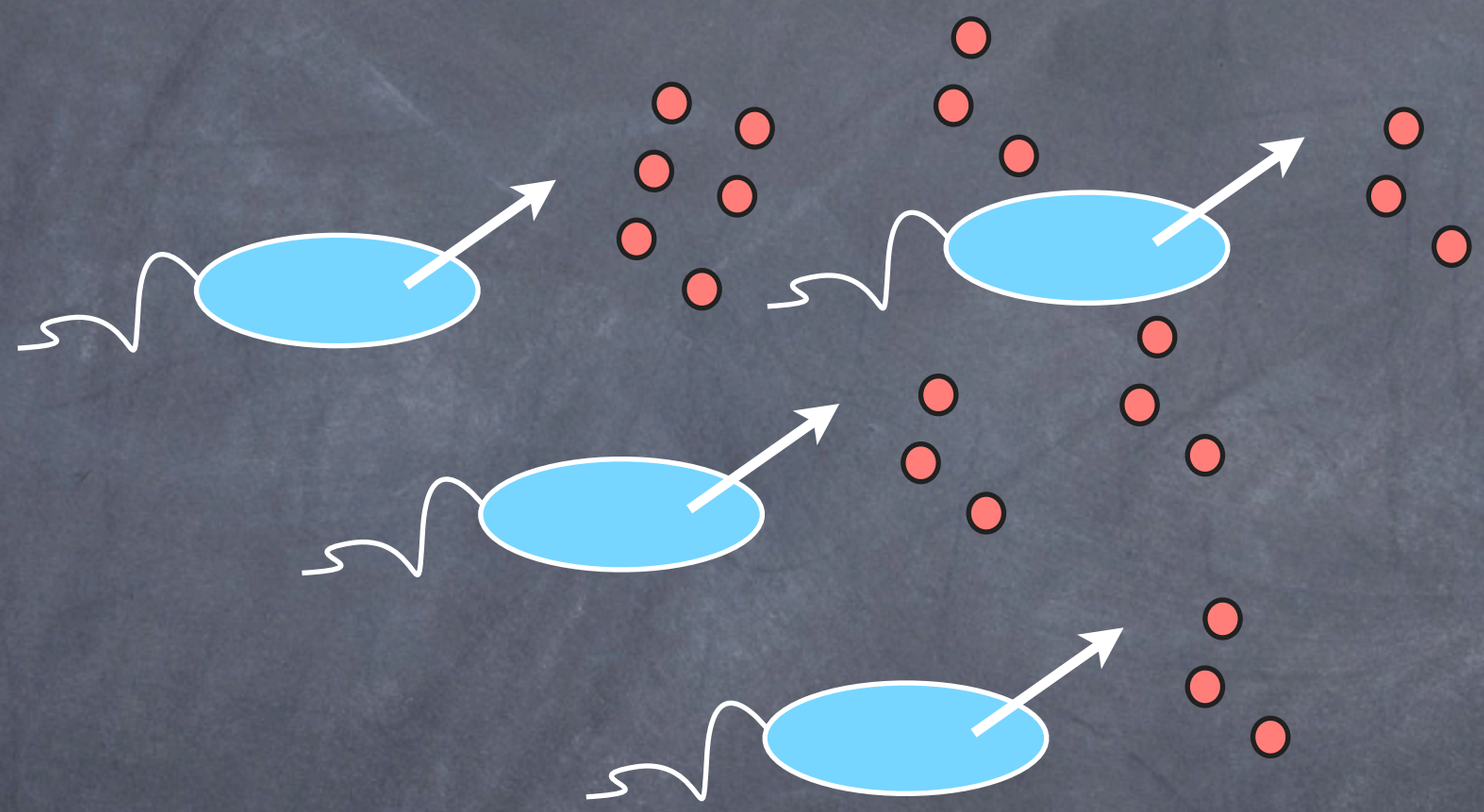




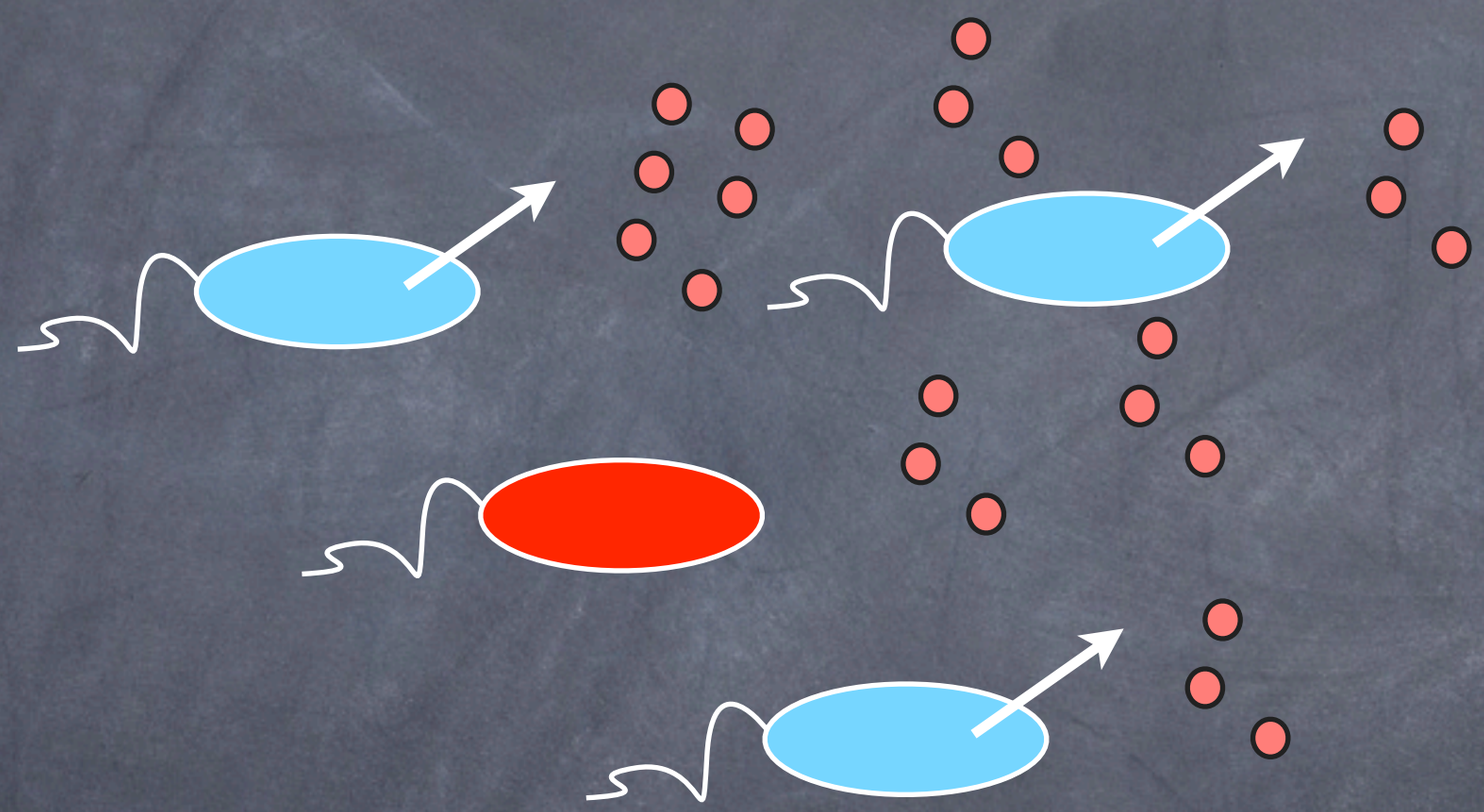
The public goods dilemma (PGD)

- imagine a situation in which individuals contribute to a public good (or make use of a public good resource)
- The Tragedy of the commons (found in every major transition in Evolution): the optimal behavior of the individual does not correspond to that of the group
- every-day examples: CO_2 pollution, tropical deforestation, climate change, ...

PGD are also found in bacteria



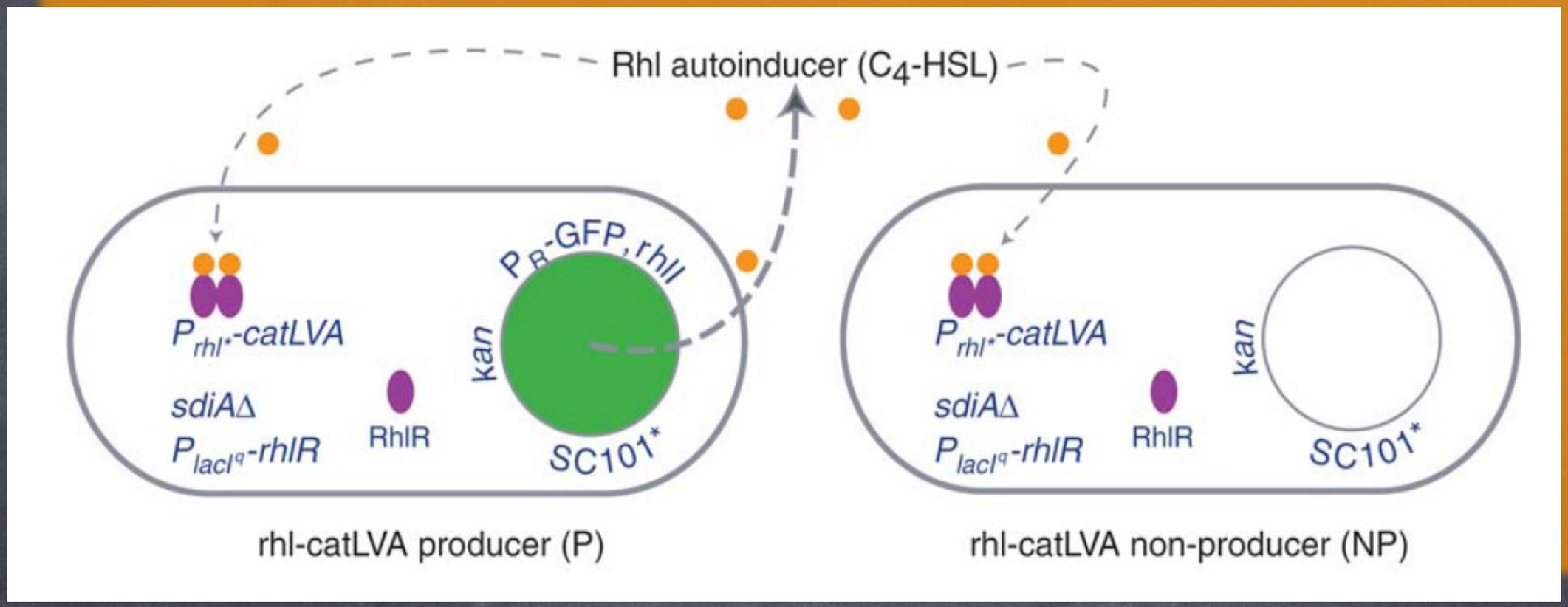
one individual bacterium might not 'feel' to cooperate: the 'cheater'



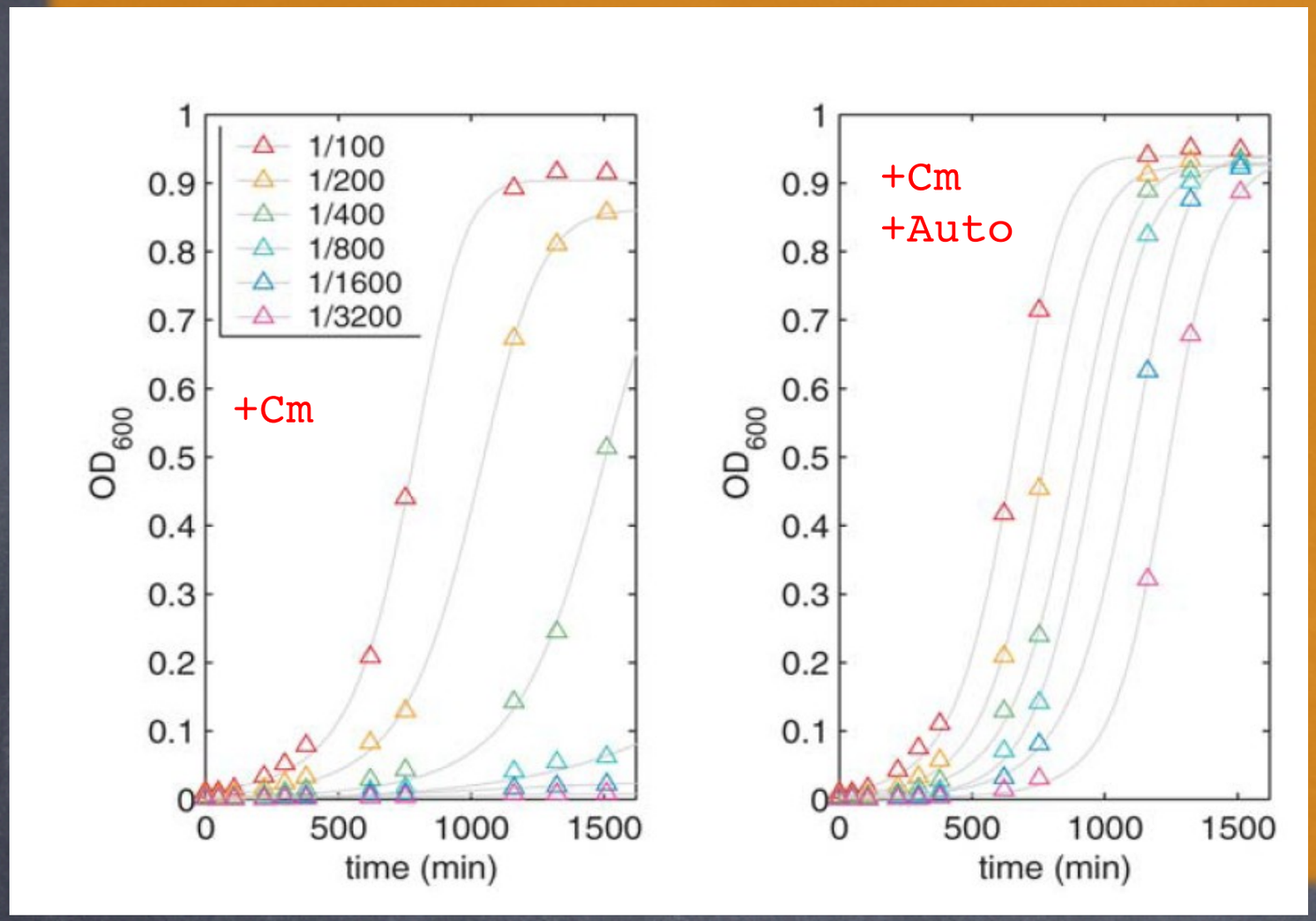
- cheaters benefit from the PG but pay no cost!

let's get more specific

JS Chuang et al Science 323,272(2009)



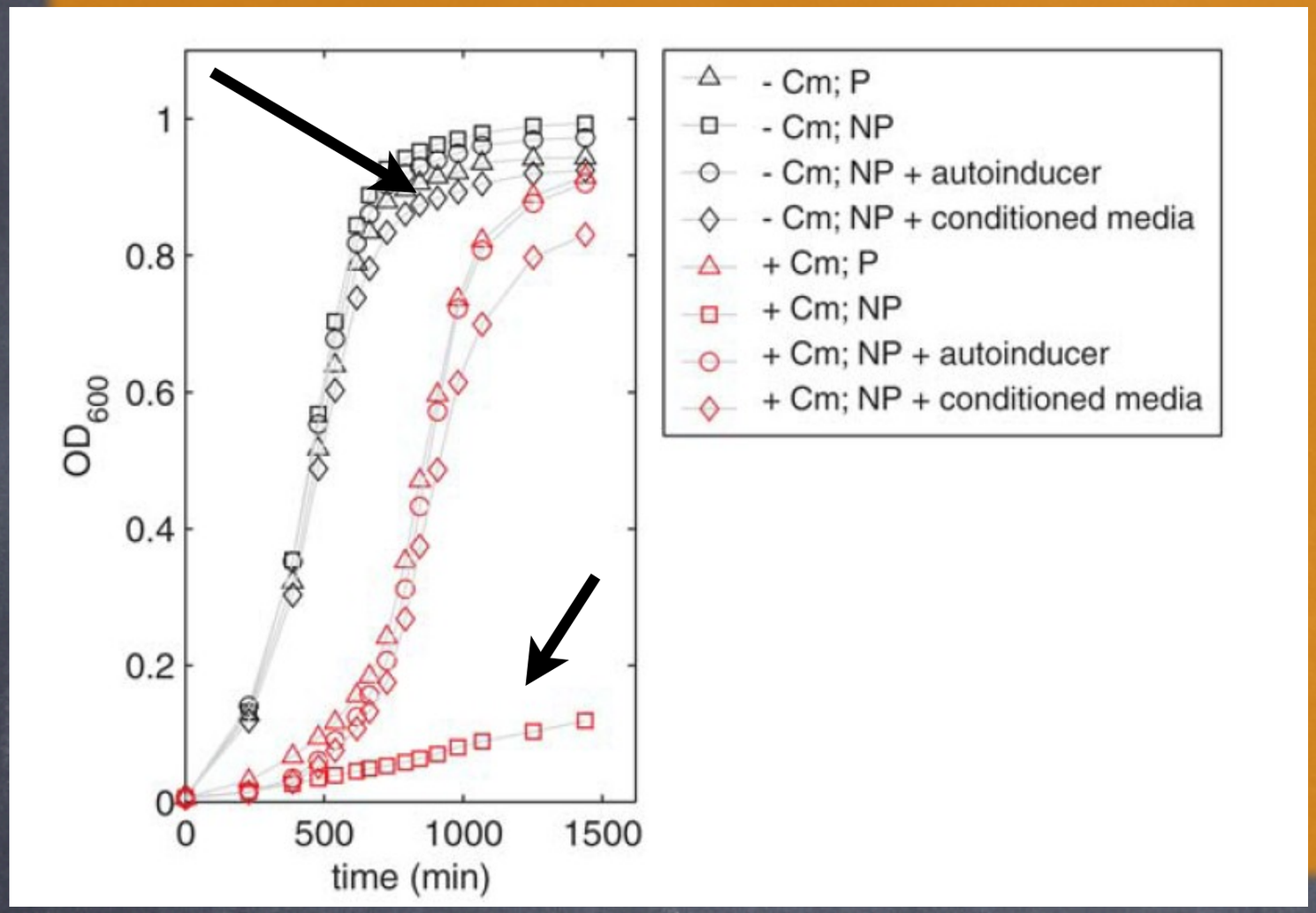
let's get more specific



+ antibiotic!

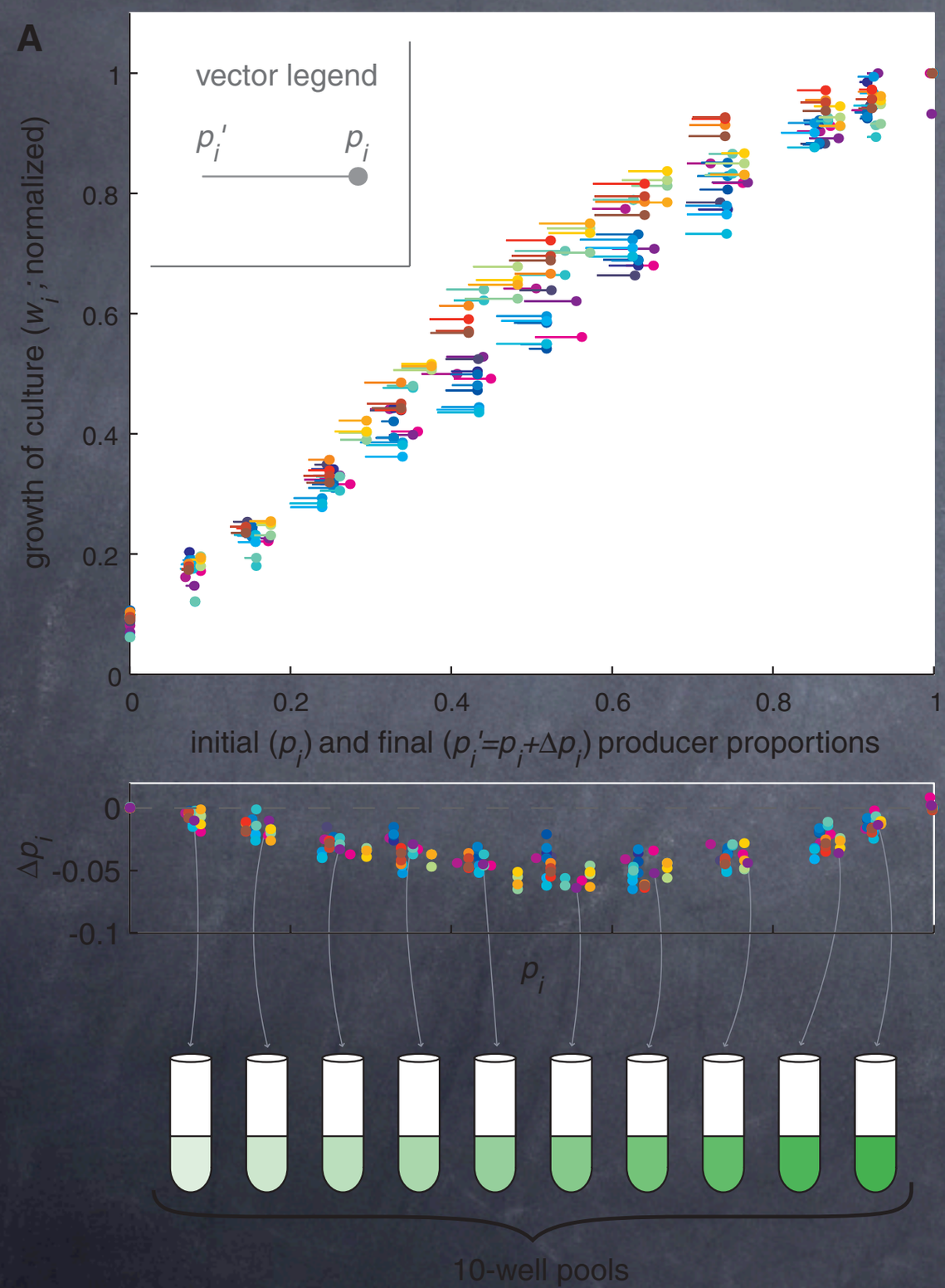
- producer growth is density dependent (bigger dilution --> less bacteria --> less PG)
- AUTOinducer is limiting

let's get more specific

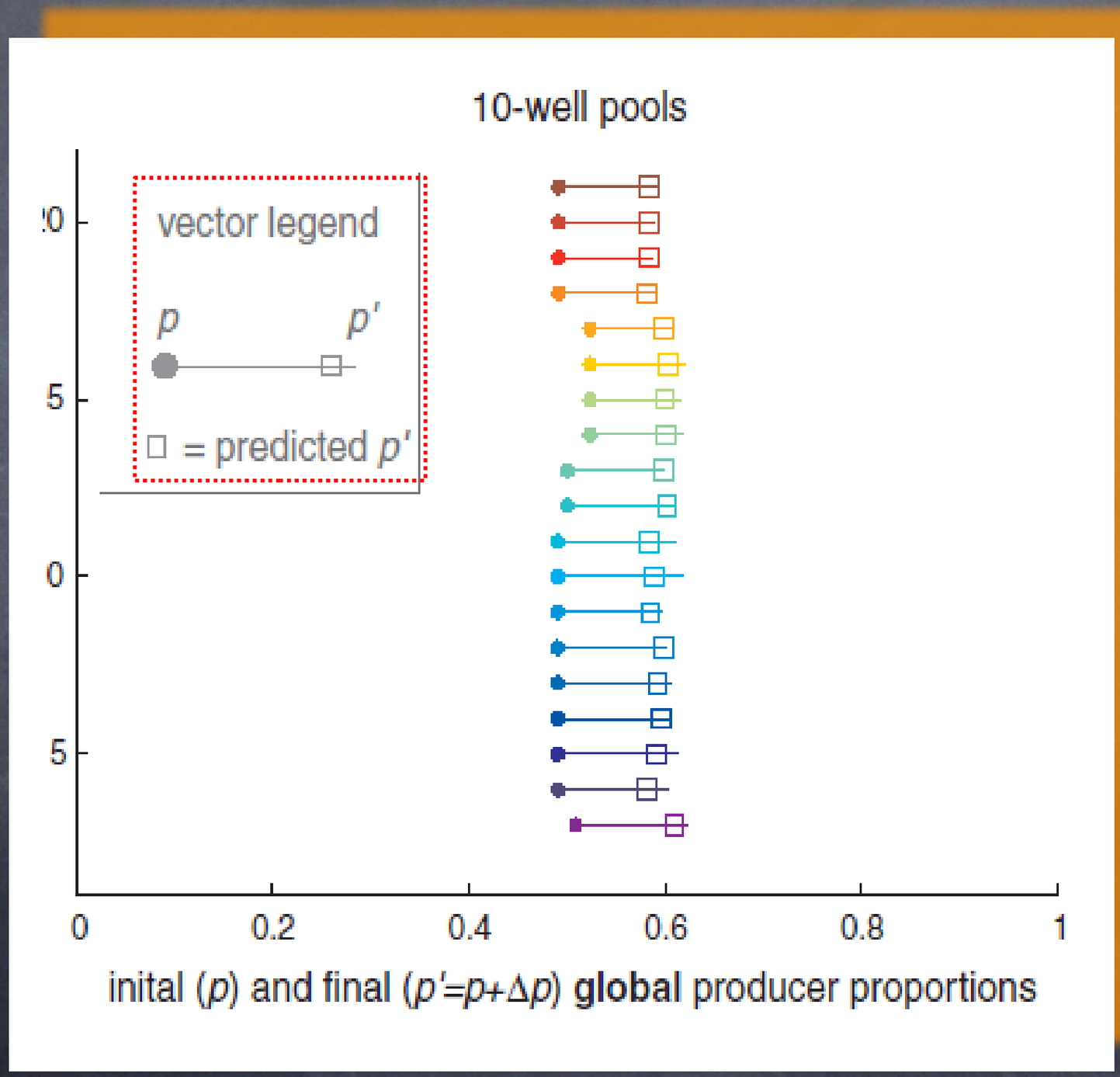


- producer grow faster than non-producers (cheaters); starting from same initial density

non-producers win in any mixture of non-producers and producers ... ...



... but total proportion of producers grows overall !·$%·!??



consider a simple model

- population of n individuals

- producers generate PG with efficiency r at cost c

consider a simple model

- $W_P = W_0 + rc\,(np - 1)/(n-1) - c$
- $W_{nP} = W_0 + rcnp/(n-1)$

Some numbers $n = 100$, $p = 1/2$, $W_0 = 10$, $r = 5$, $c = 1$

$W_P = 11.47 > W_0$

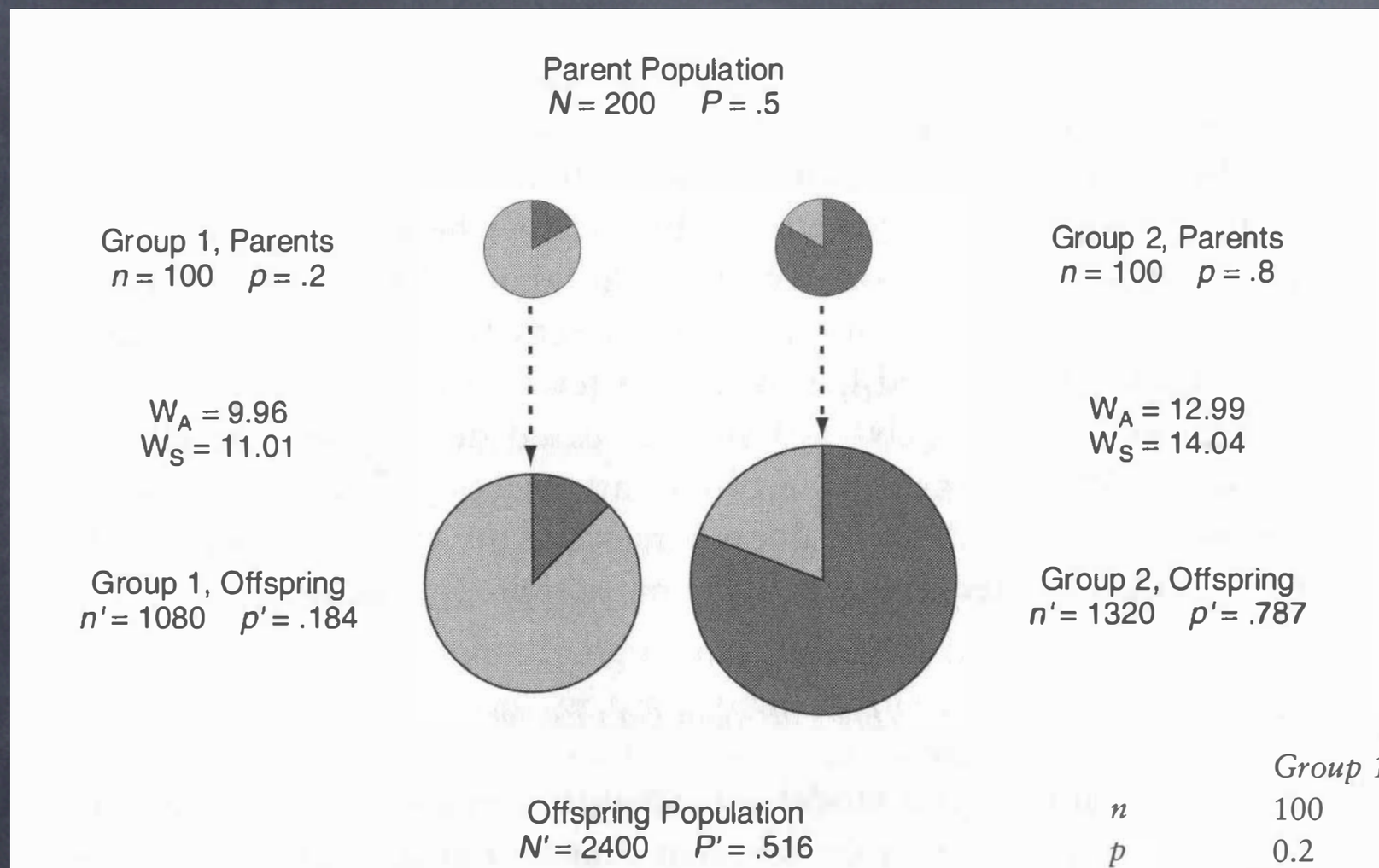
$W_{nP} = 12.53 > W_0$

Offspring $n' = n\,[p\,W_P + (1-p)\,W_{nP}] = 1200$

$p' = npW_P/n' = 0.478$

DECLINE OF PRODUCERS!

but say we have two groups

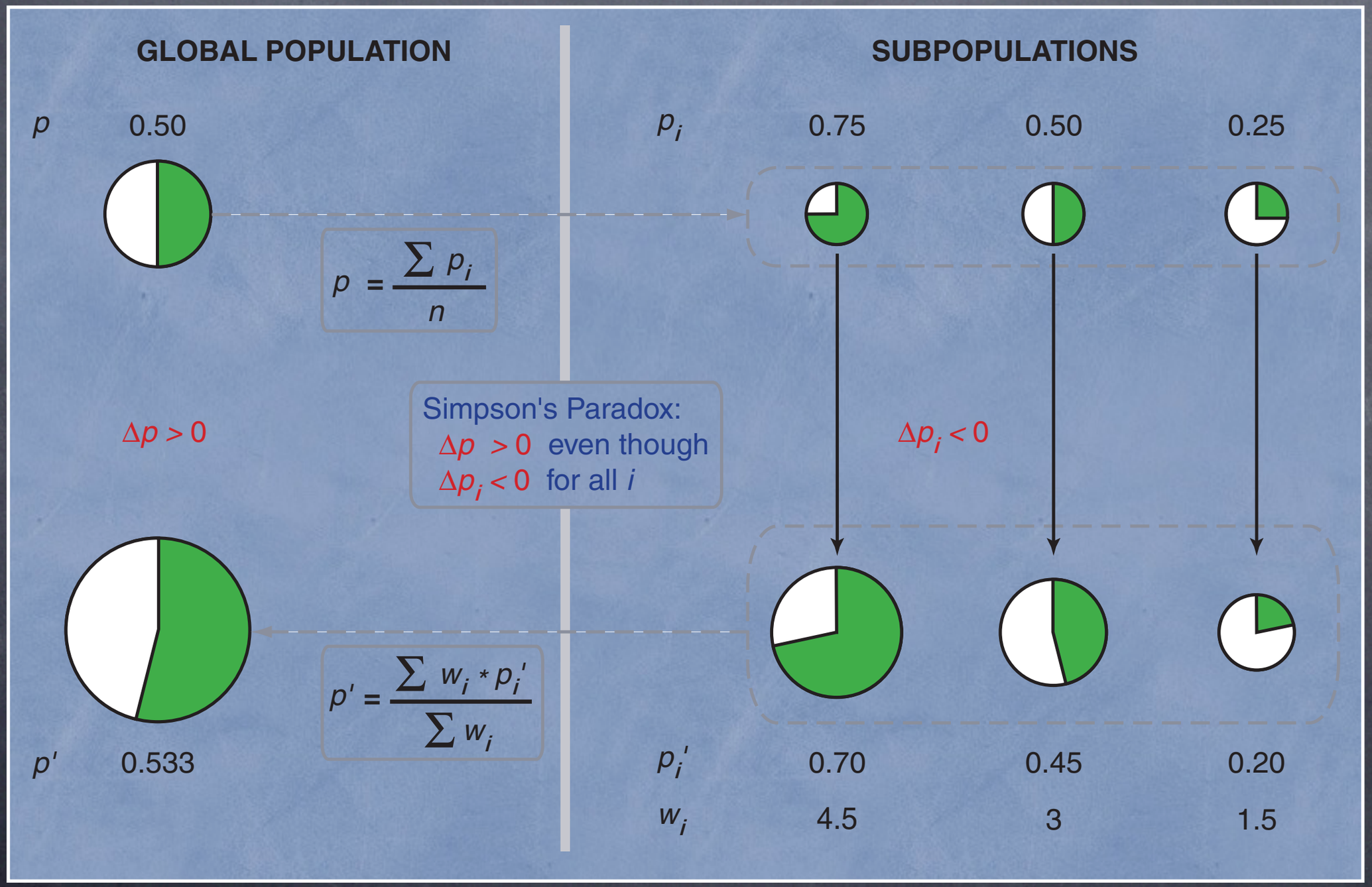


	Group 1	*Group 2*
n	100	100
p	0.2	0.8
W_A	$10 - 1 + 5(19)/99 = 9.96$	$10 - 1 + 5(79)/99 = 12.99$
W_S	$10 + 5(20)/99 = 11.01$	$10 + 5(80)/99 = 14.04$
n'	1080	1320
p'	0.184	0.787

	Global population
N	$100 + 100 = 200$
P	$[0.2(100) + 0.8(100)]/200 = 0.5$
N'	$1080 + 1320 = 2400$
P'	$[0.184(1080) + 0.787(1320)]/2400 = 0.516$

- SIMPSON's paradox

it's all about 1) structure, 2) variance and 3) differential contribution

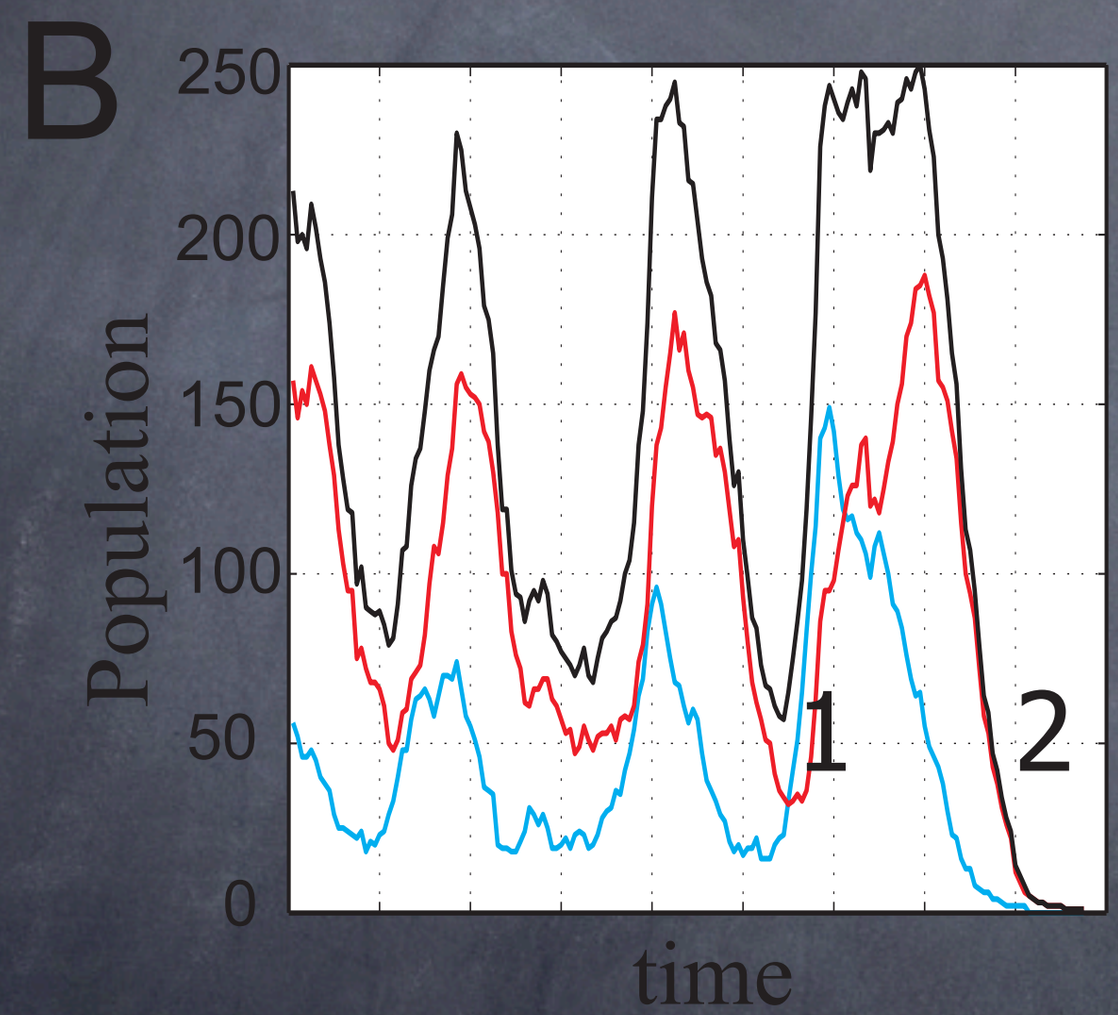


Designing

sustainable

communities

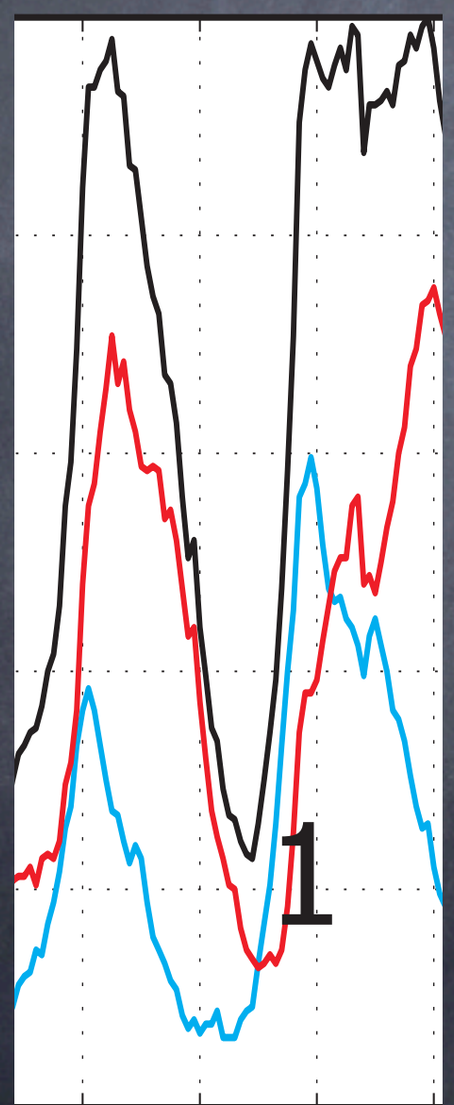
imagine that PG is critical for growth of a structured population

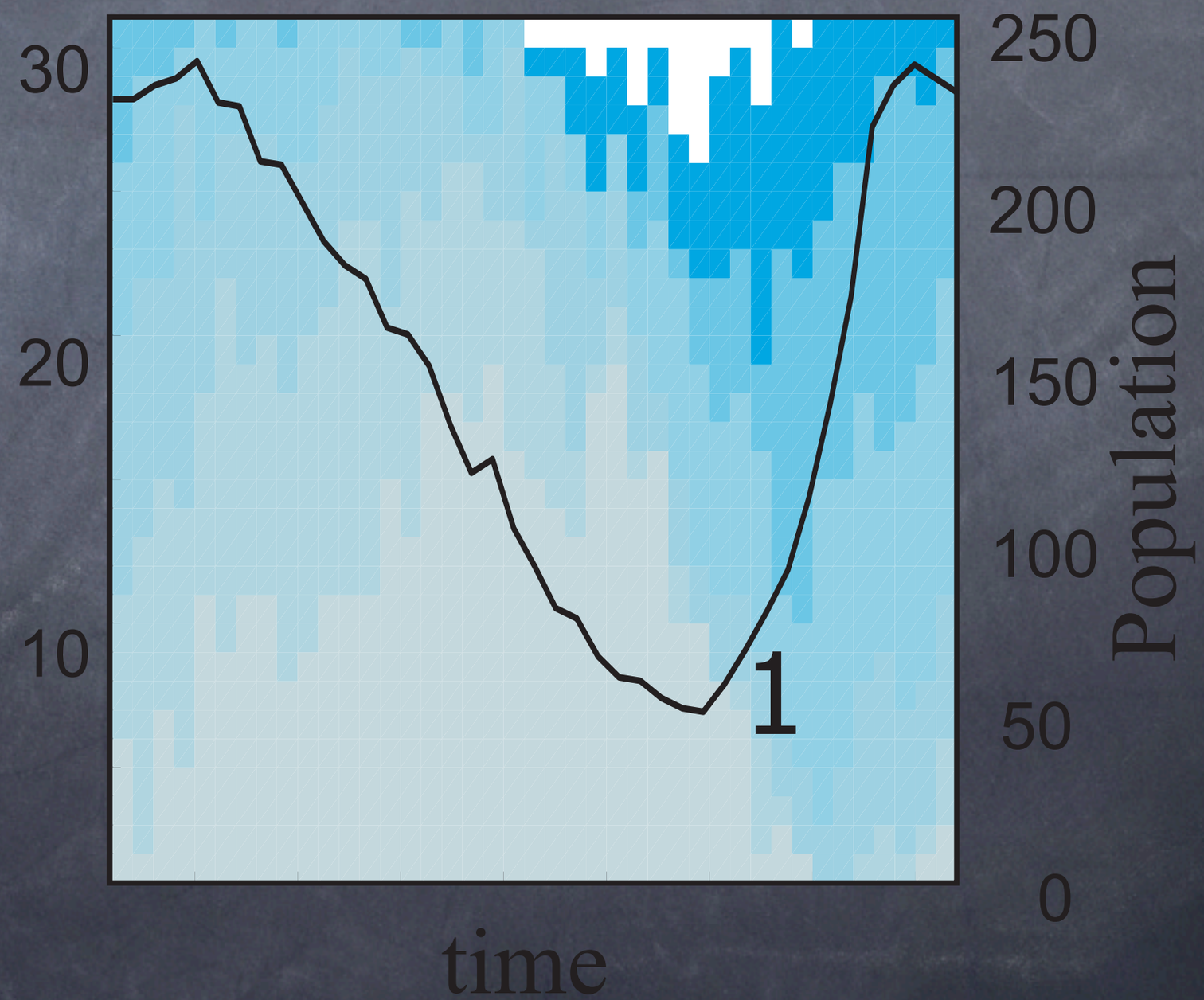


M Cavaliere & JF Poyatos (2012)

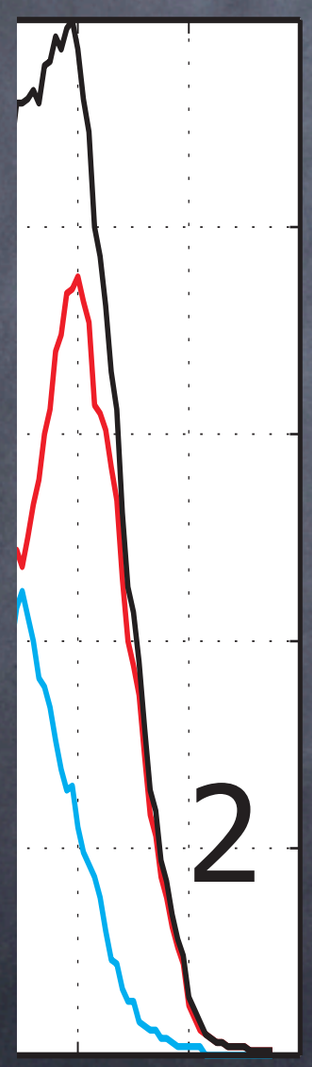
- cheaters can lead to extinctions ... sometimes

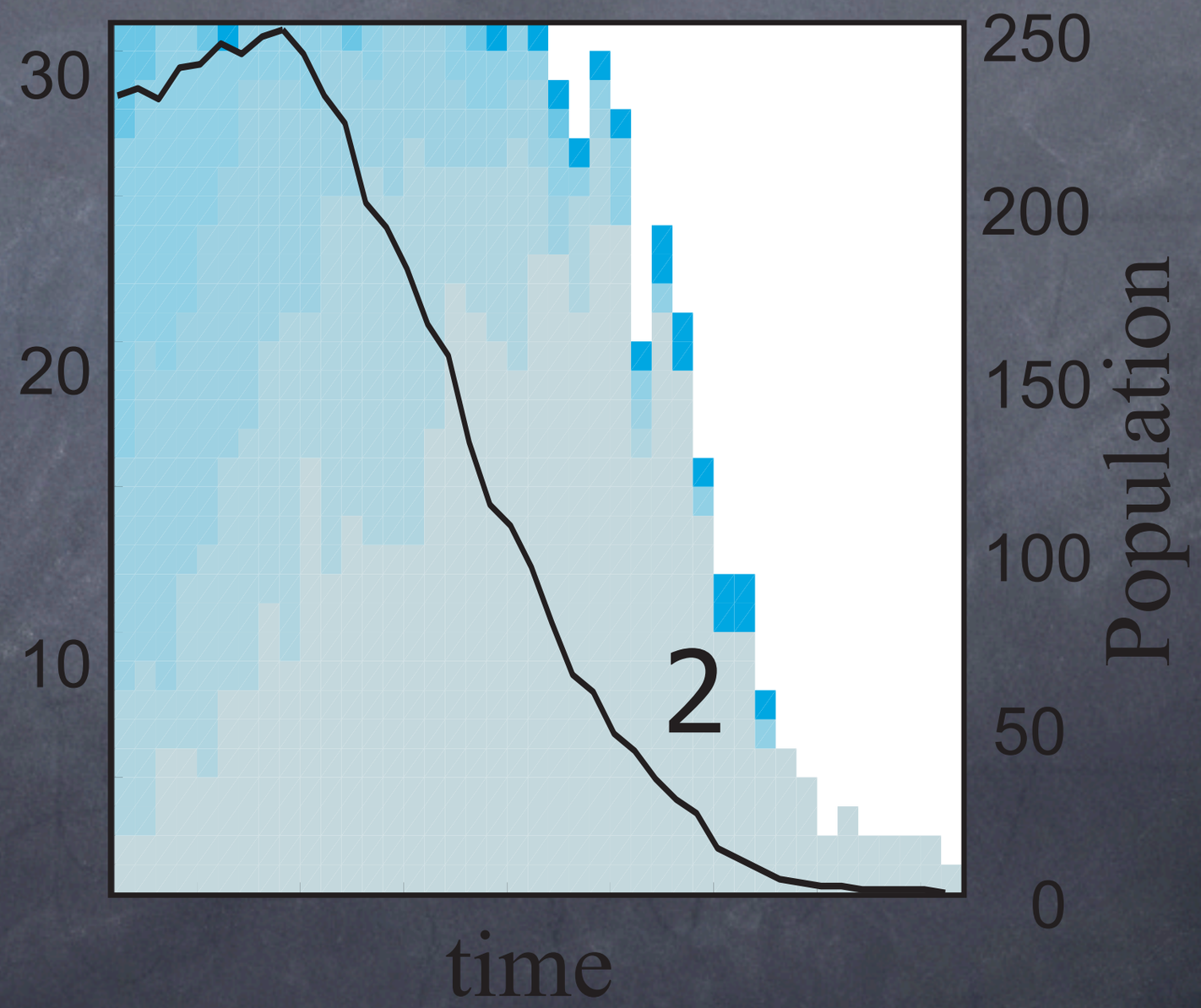
Simpson's paradox helps solving the threat of cheaters



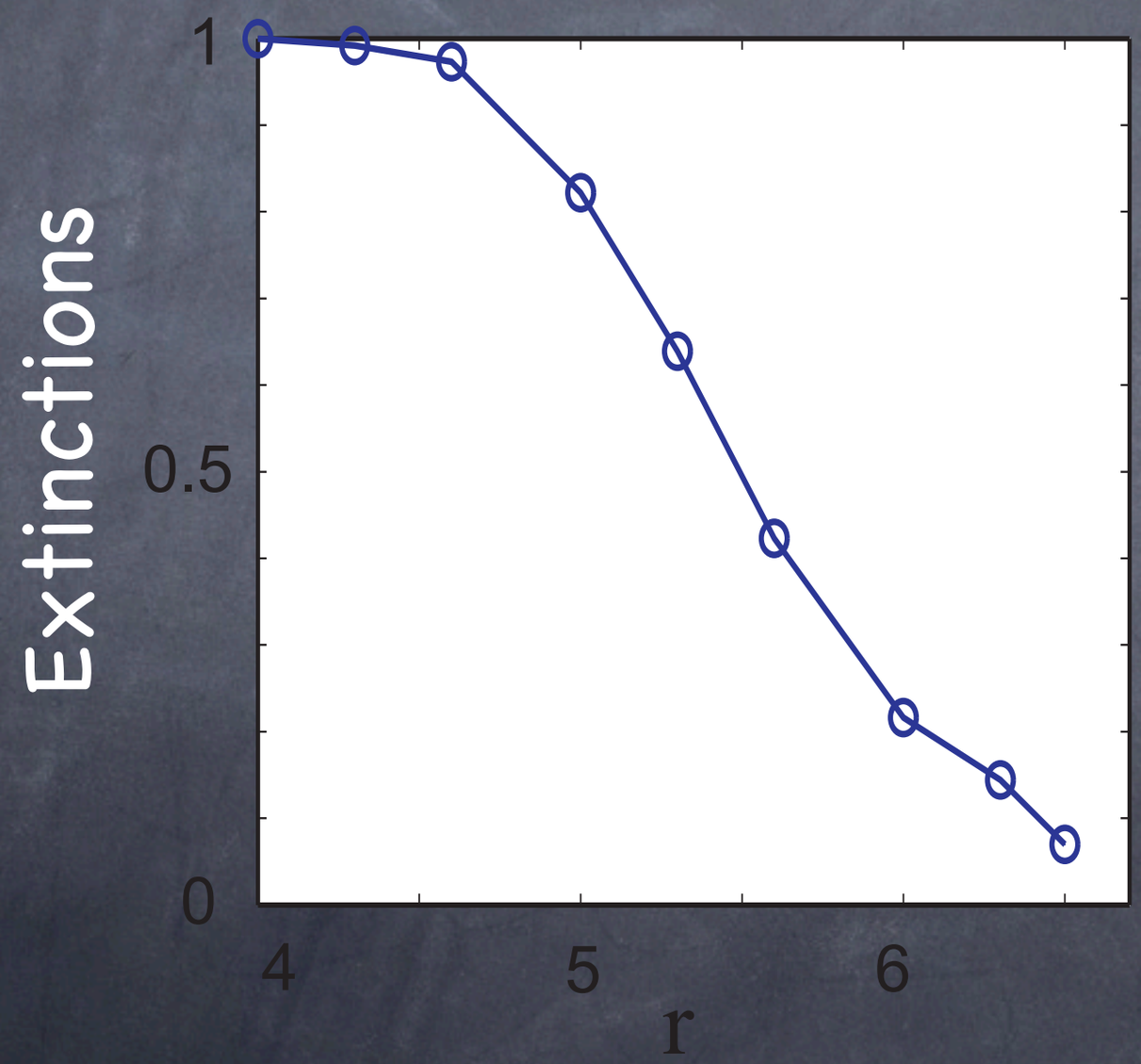


Simpson's paradox helps solving the threat of cheaters ... not always!





Frequency of extinctions depend on efficiency r



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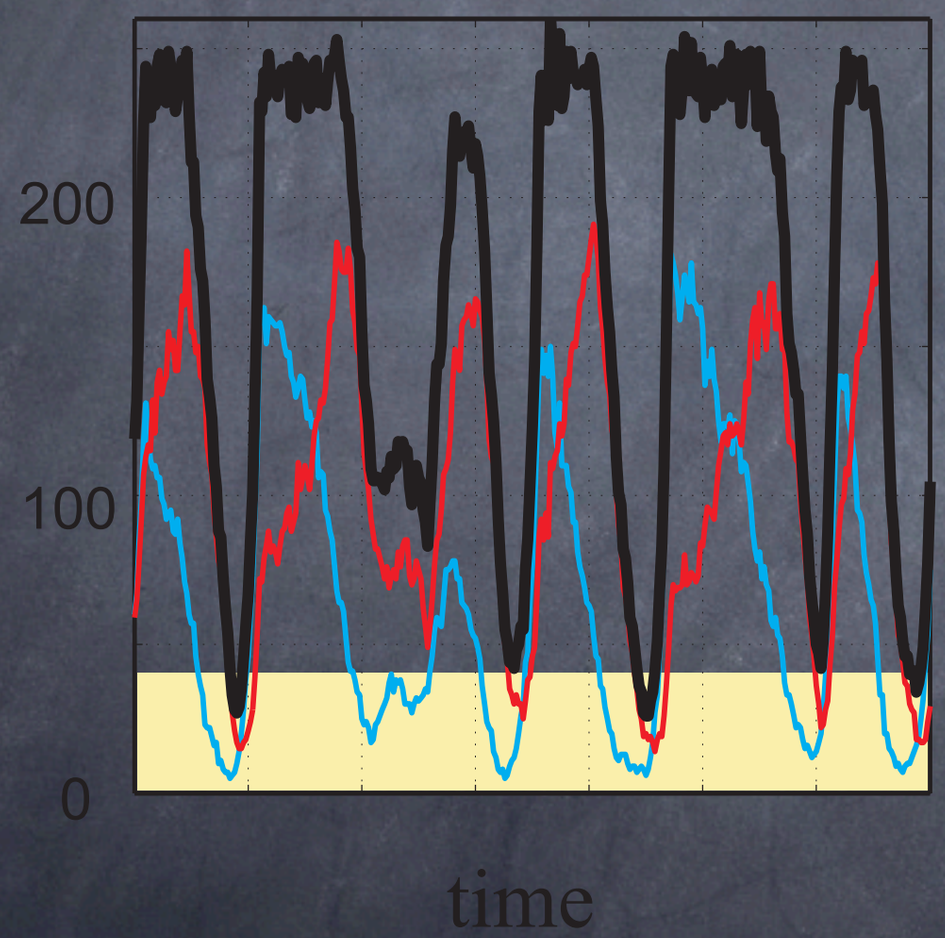
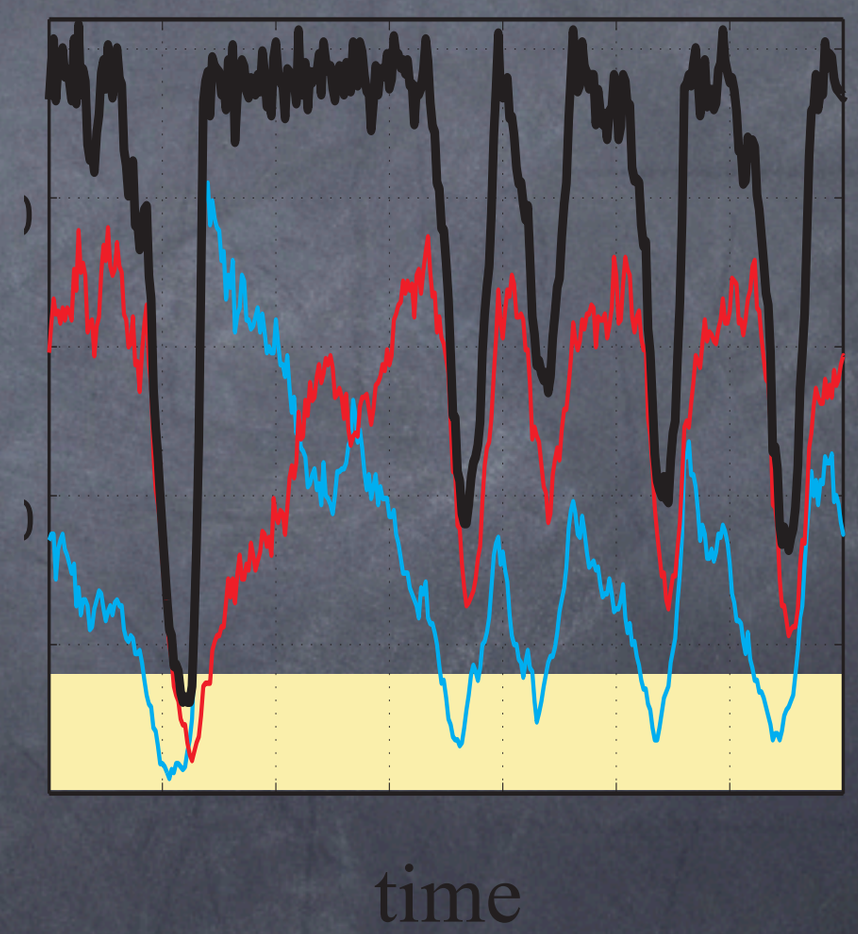
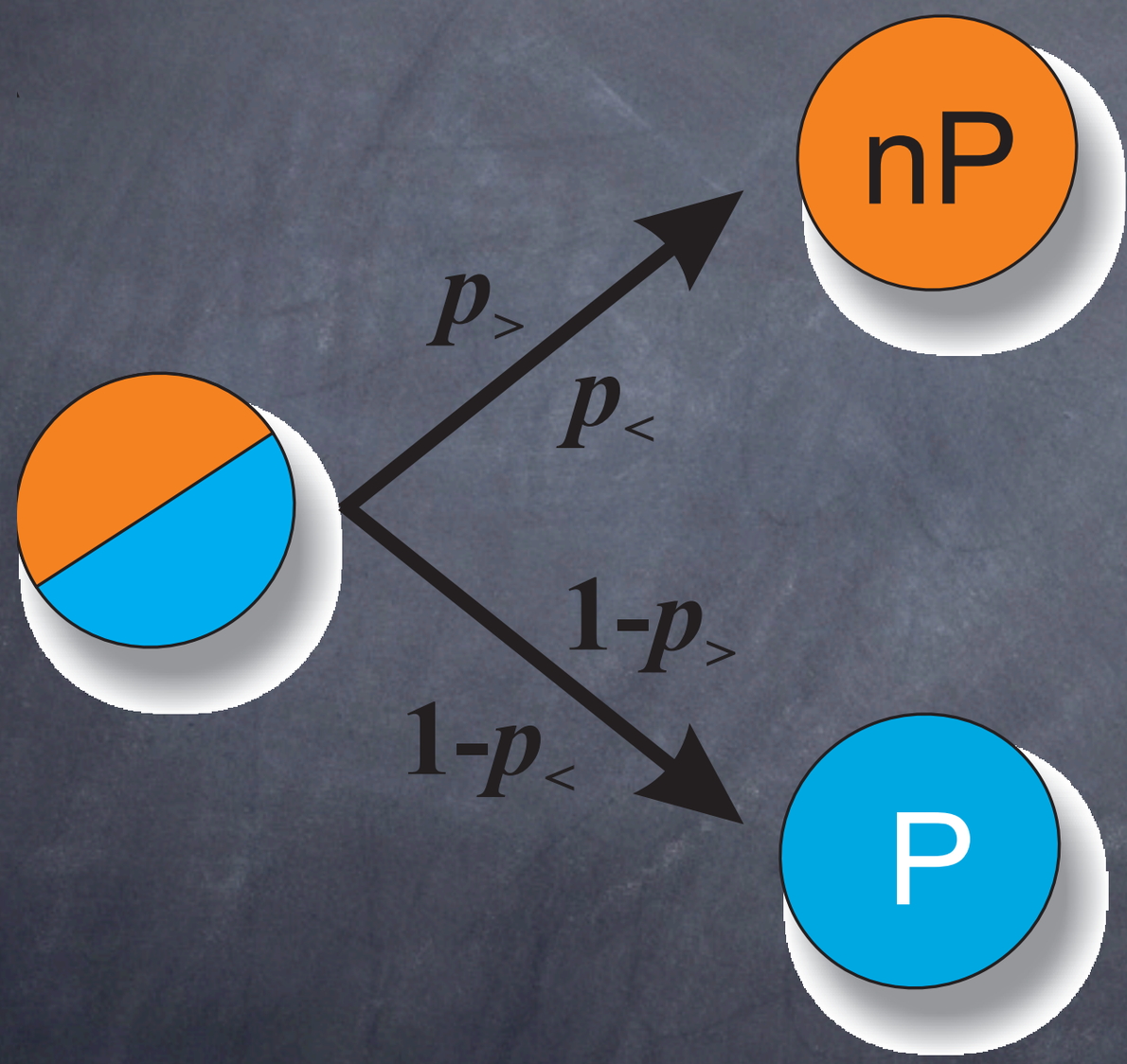




- low r
- high r

Plasticity leads to sustainability

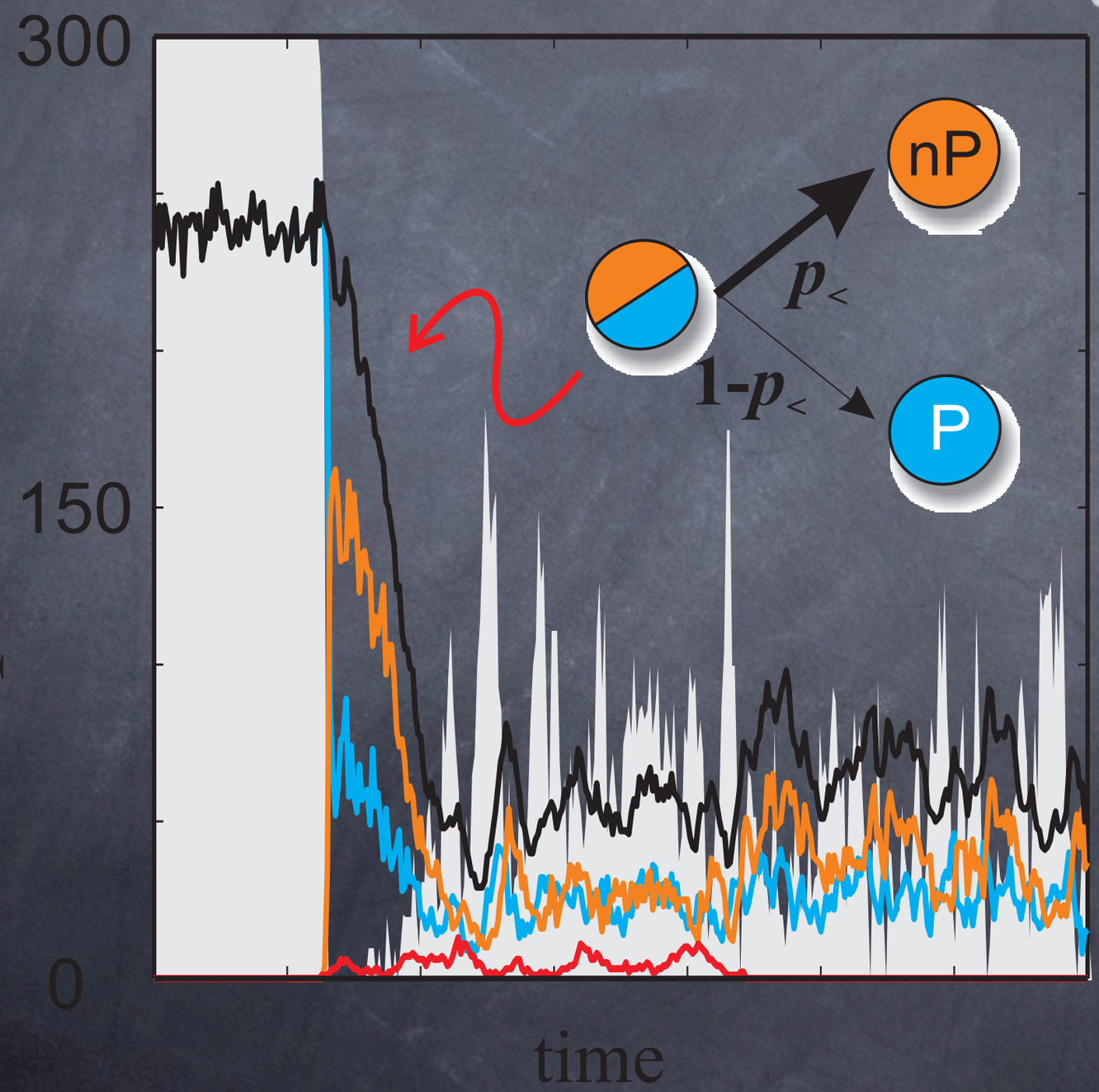


$$\frac{p_>}{p_<}$$

social threshold

Be a producer when most members are also producers

- Positive PLASTICITY



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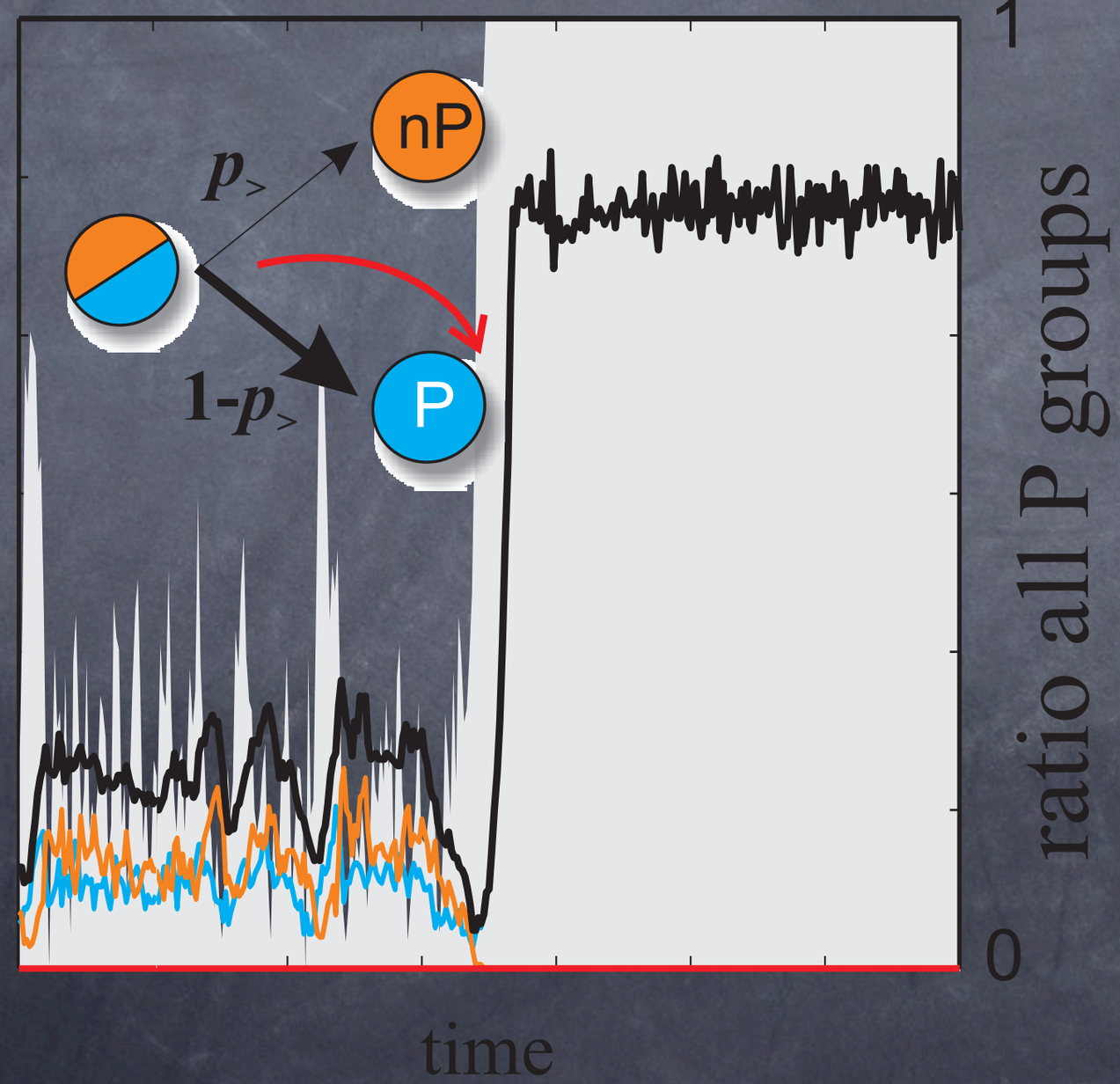
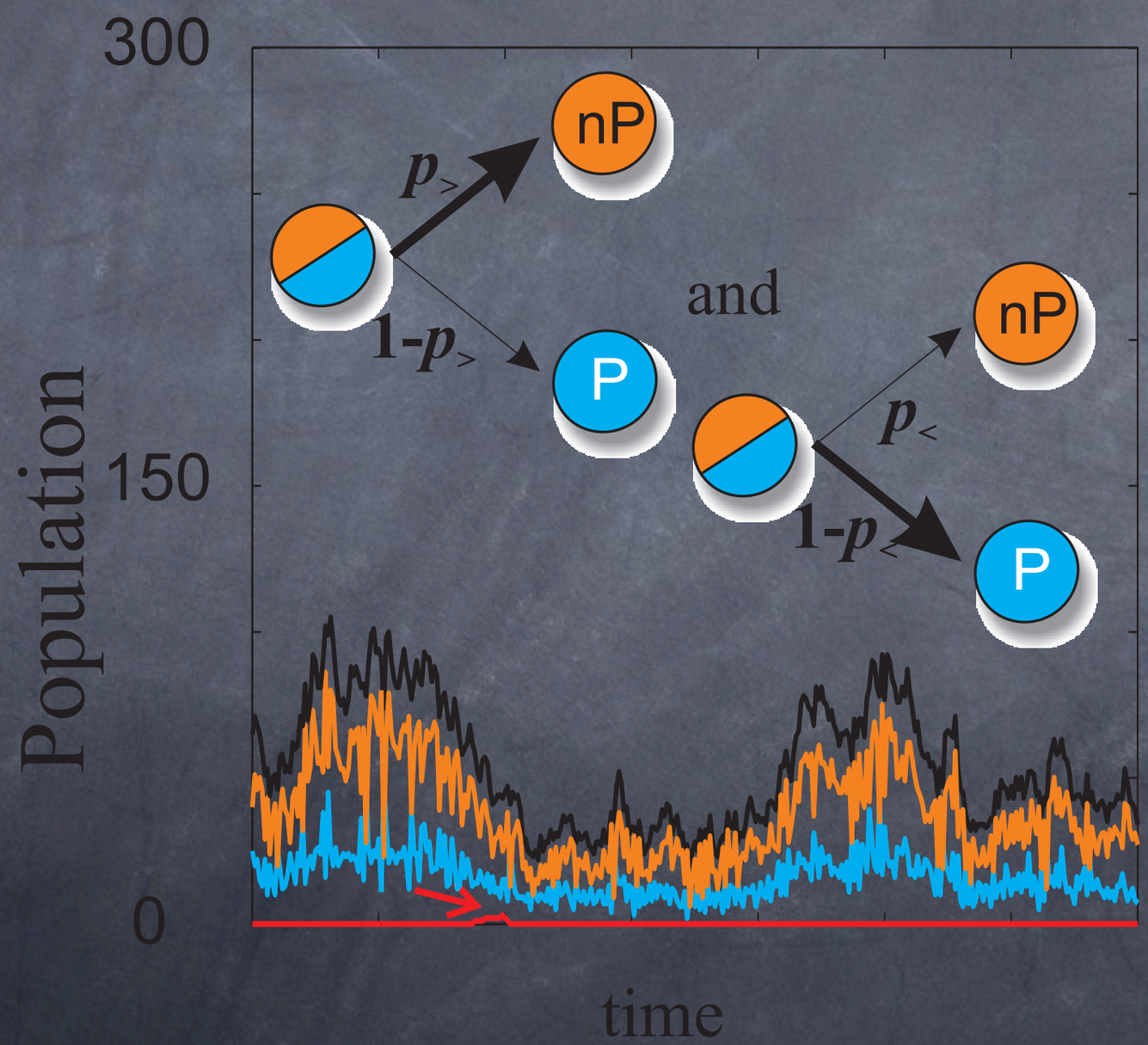
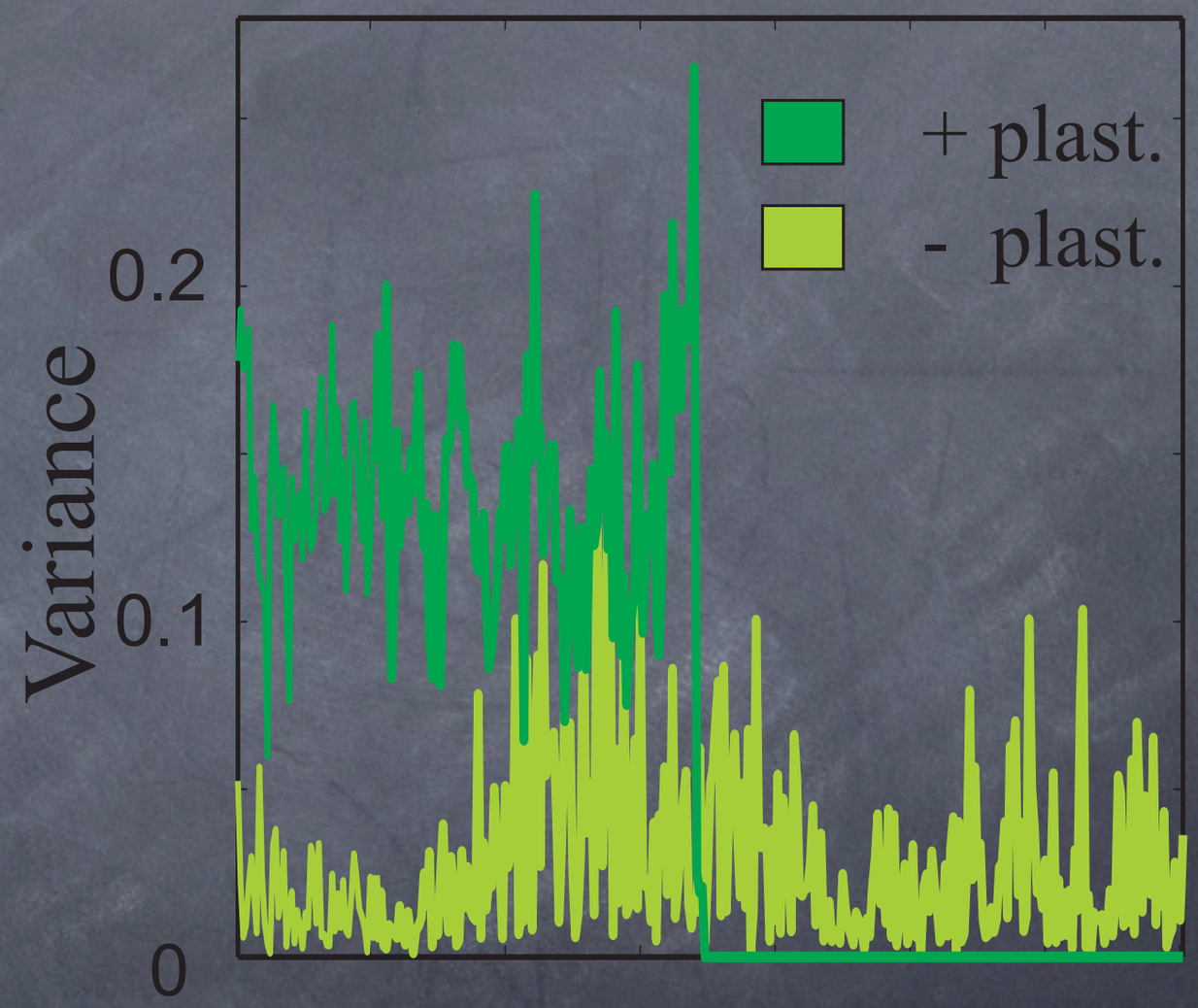


Be a producer when there is an excess of non-producers

- Negative PLASTICITY



- Positive PLASTICITY
- small groups,
- small efficiency
- very reactive response



- Negative PLASTICITY
- big groups,
- high efficiency
- minimal diversity