markets, social opportunities, and the evolution of fairness

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joint work with nicolas baumard

Chaire Modélisation Mathématique et Biodiversité - X - Juin 2012

Humans do cooperate...

- **collect and bring resources to camp for others** (water; fire wood; medicinal plant; game and other food sources)
- **perform an activity that benefits all** (clean the camp; build a hut; cook; light a fire; cut a trail; make a bridge; remove dangerous obstacles from a trail)
- **perform an activity that benefits someone else** (carry, teach, tend, feed others' children; carry game; tracks a prey when ego has no arrow; climb tree to knock down fruits; open a "window" in a tree to test for palm starch; cut down tree for others to collect fruits; call another to the pursuit of a prey; wait for others to join a pursuit; bring a bow for others in a pursuit; allow another to shoot at ego's prey, dig out an armadillo or extract honey; climb a tree to flush a monkey; care for others when they are ill; give advice; keep insect pests away from others; groom others; provide company; make, fix tools, lend tools)
- **provide information to others** (go back on trail to warn others of a wasp nest, fresh jaguar tracks or poisonous snake; yells whereabouts of escaping prey, or location of a resource)

(Hill 2002; see also Kaplan and Gurven 2005; Ichikawa 1983; Bailey 1991; Smith 1991)

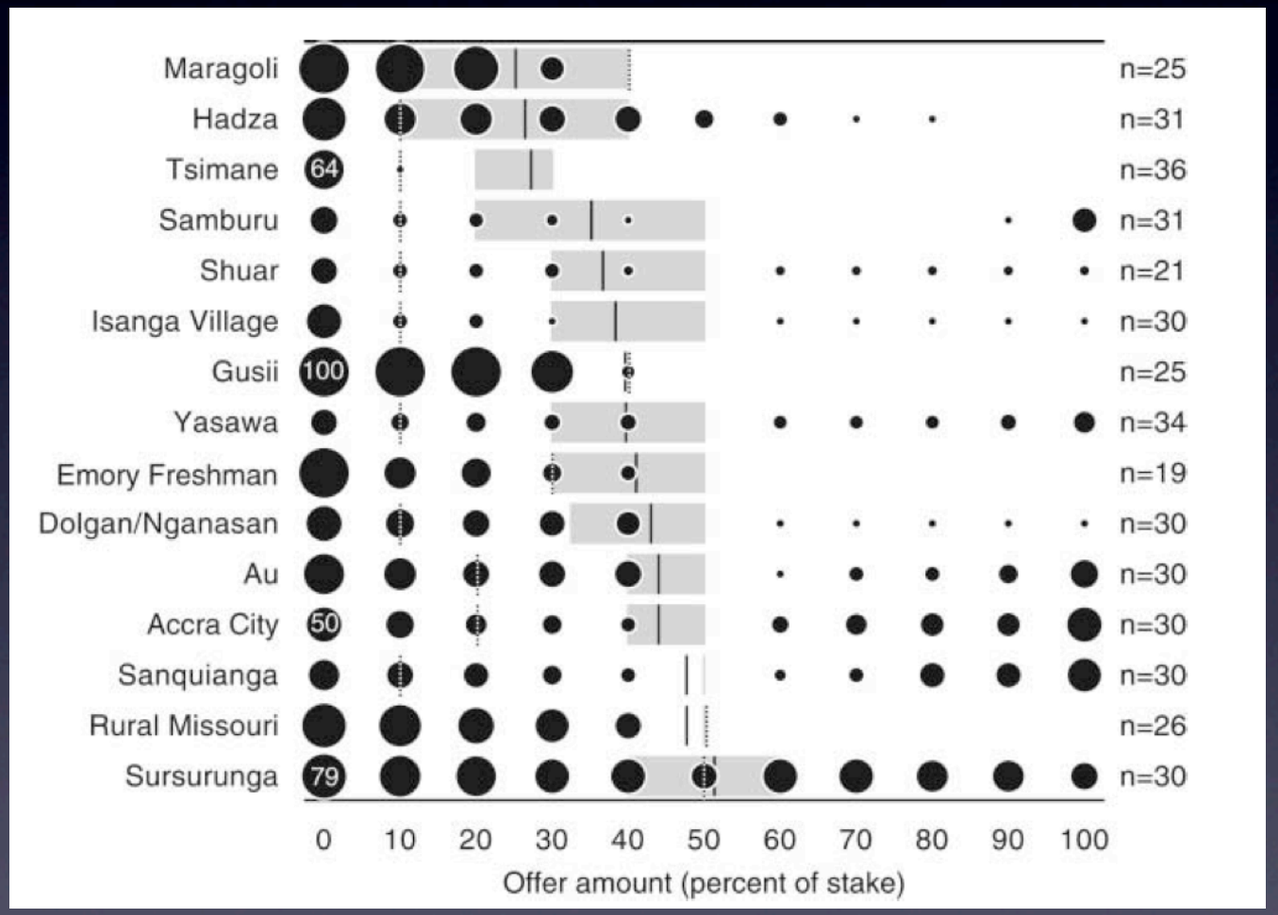
...in a specific manner

- cooperation generates benefits
- we have strong intuitions regarding the way to divide them

fairness in anthropology

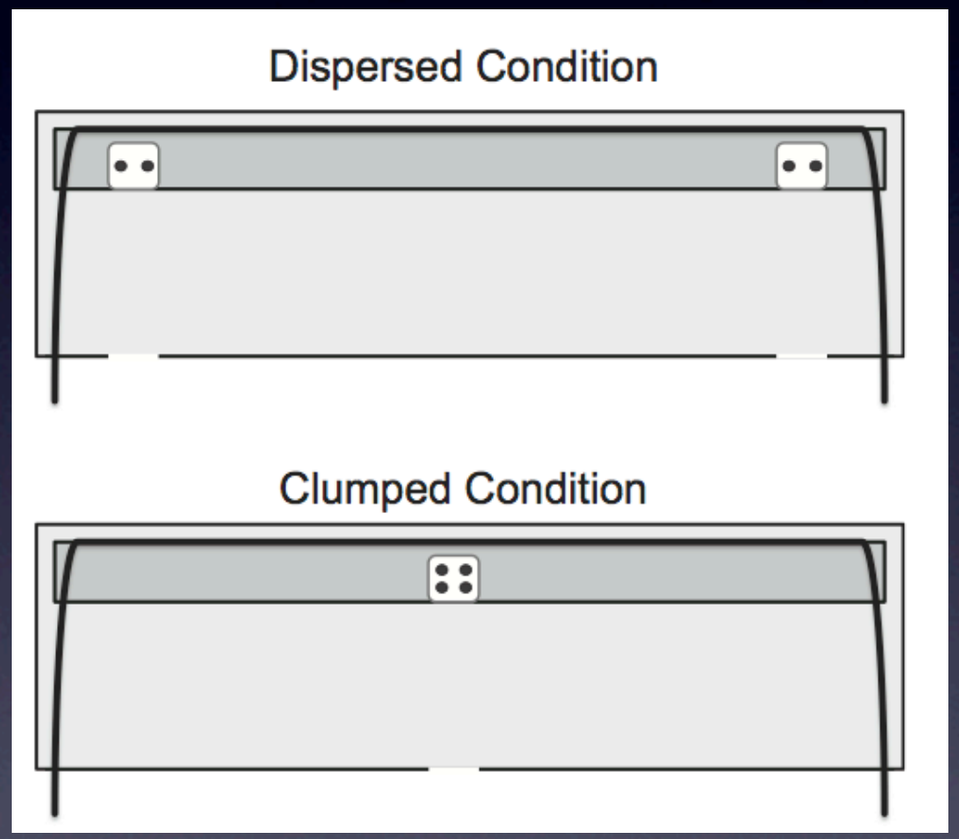
(Alvard and Nolin 2002; see also Bailey 1991; Gurven 2004; Baumard et al. in press)

fairness in experimental economics

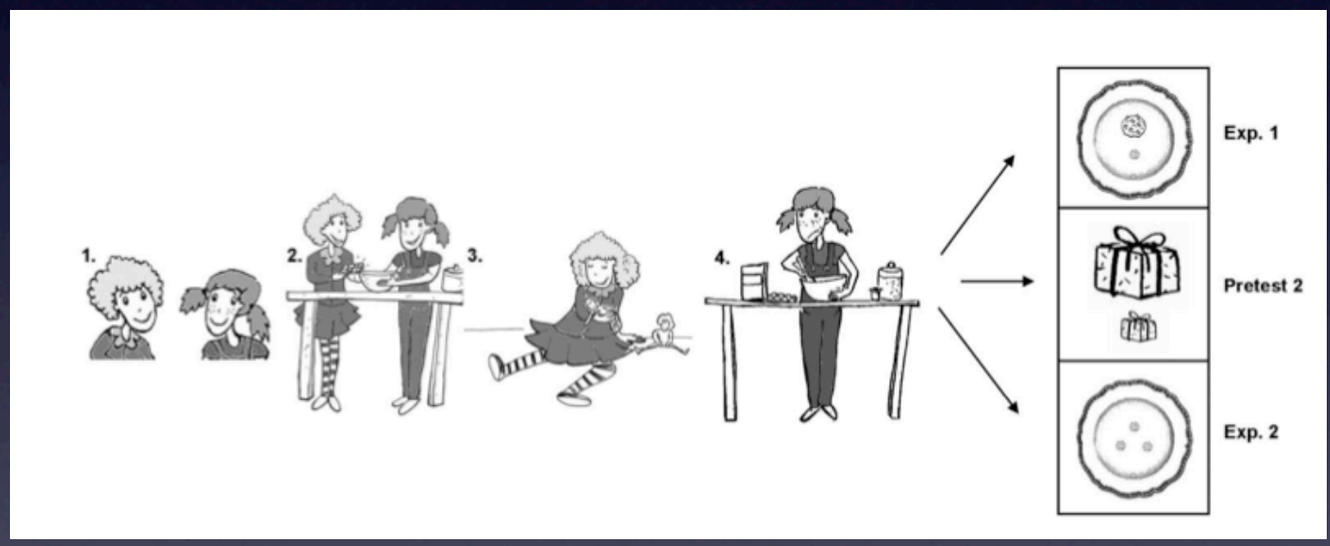


Guth et al. 1982; Camerer 2003; Henrich et al.

fairness in developmental psychology



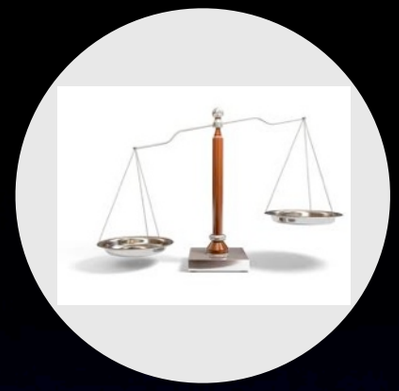
Warneken et al. 2010



Baumard et al. 2011

two questions on cooperation

- explain the existence of cooperation, as opposed to selfishness
- explain the fine grained properties of cooperation, in particular the division of its benefits



cultural group selection

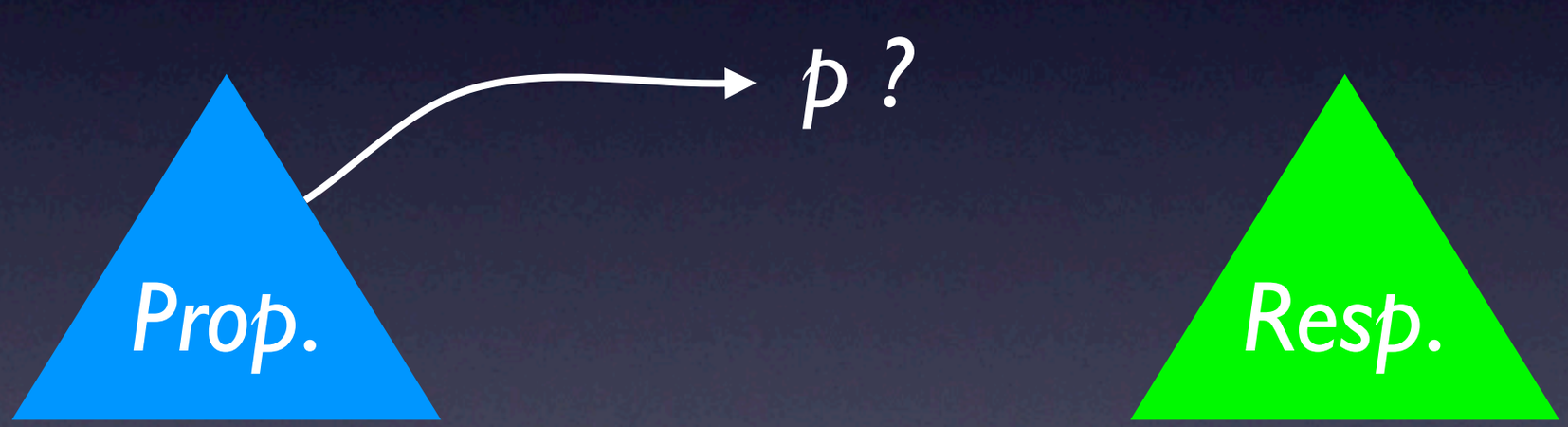
sharing a surplus benefit

Let us take for granted the existence of a cooperative interaction between two individuals, generating a surplus benefit

Individuals then bargain over
the distribution of this benefit

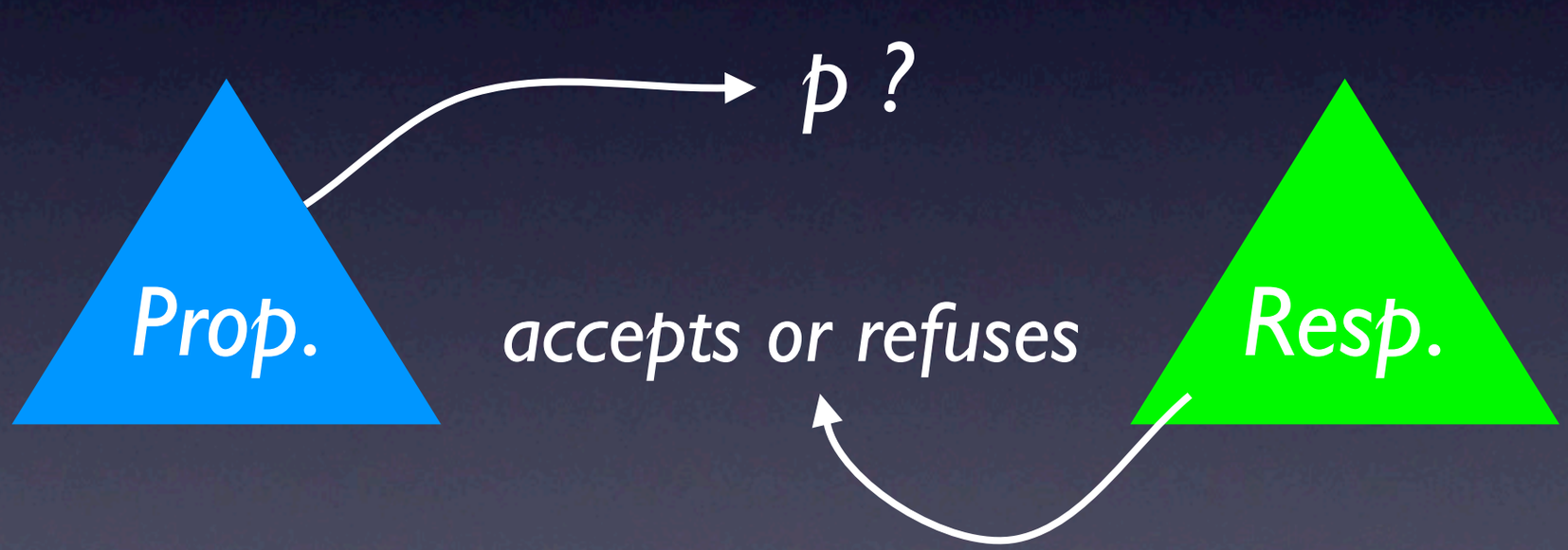
the ultimatum game

division of the fixed resource (R=1)



the ultimatum game

division of the fixed resource (R=1)



the ultimatum game

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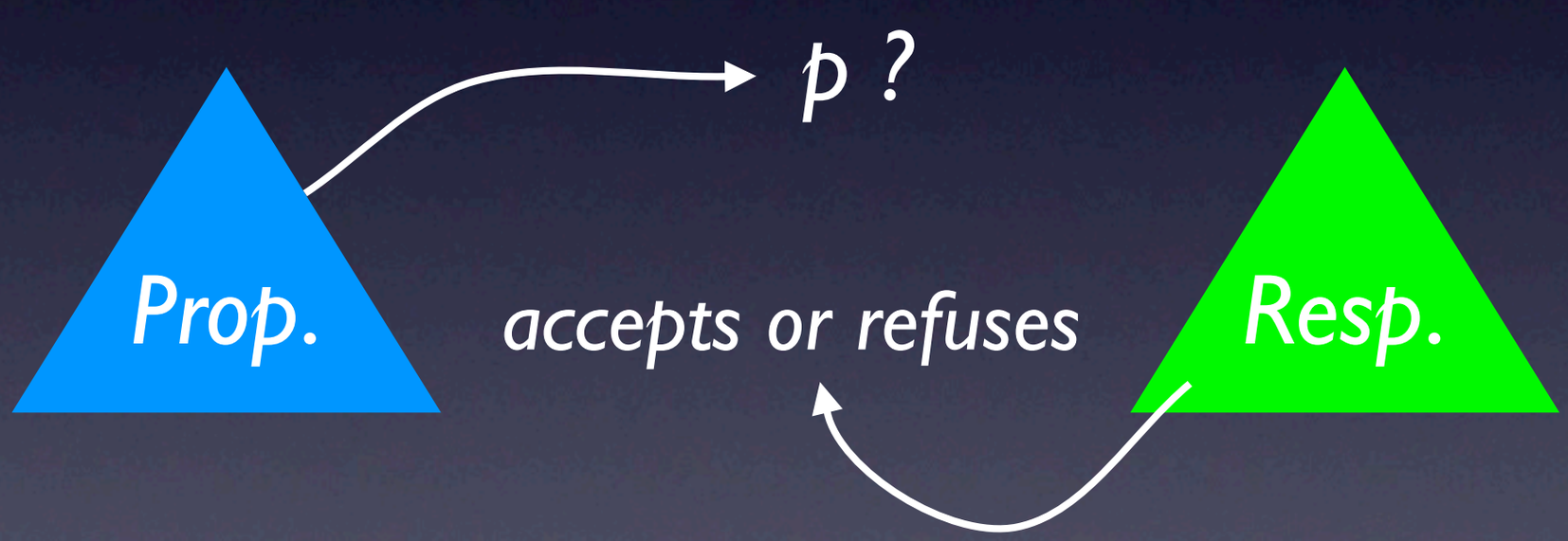


the proposer is definitely committed to the split

evolution in the ultimatum

- individuals are characterized by their offer ***p*** when playing the role of proposer and their request ***q*** when playing the role of responder

- any population with ***p=q*** is neutrally stable

evolution in the ultimatum

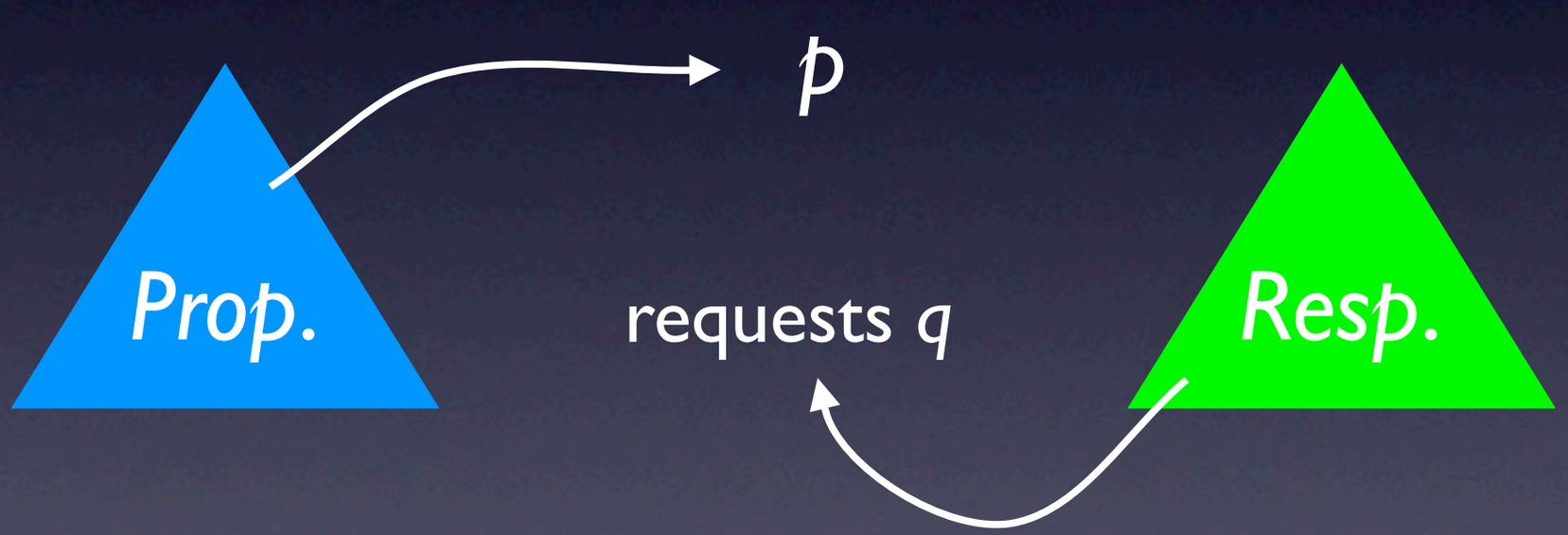
- in the presence of variability of offers (e.g. due to errors), low requests are always favored

- in result, low offers are favored and evolution leads to the lowest possible offer and request

- this is an evolutionary consequence of the ***strategic asymmetry*** of the interaction

reputation
or the inverse UG

Nowak, Page & Sigmund *Science* 2000



the proposer is informed of the reputation of his partner
and can respond to it

... with inverse results

- there is nothing to gain in offering less than requested, hence selection favors proposers who offer exactly q
- this favors responders with larger and larger requests
- eventually, responders keep the entire resource
- the strategic structure of the game is reversed

... with inverse results

- then why is the paper entitled "Fairness versus reason in the ultimatum"?
- because Nowak et al. *a priori* forbid responders to gain more than proposers
- an assumption undertaken in order to avoid a "perhaps unrealistic complication"

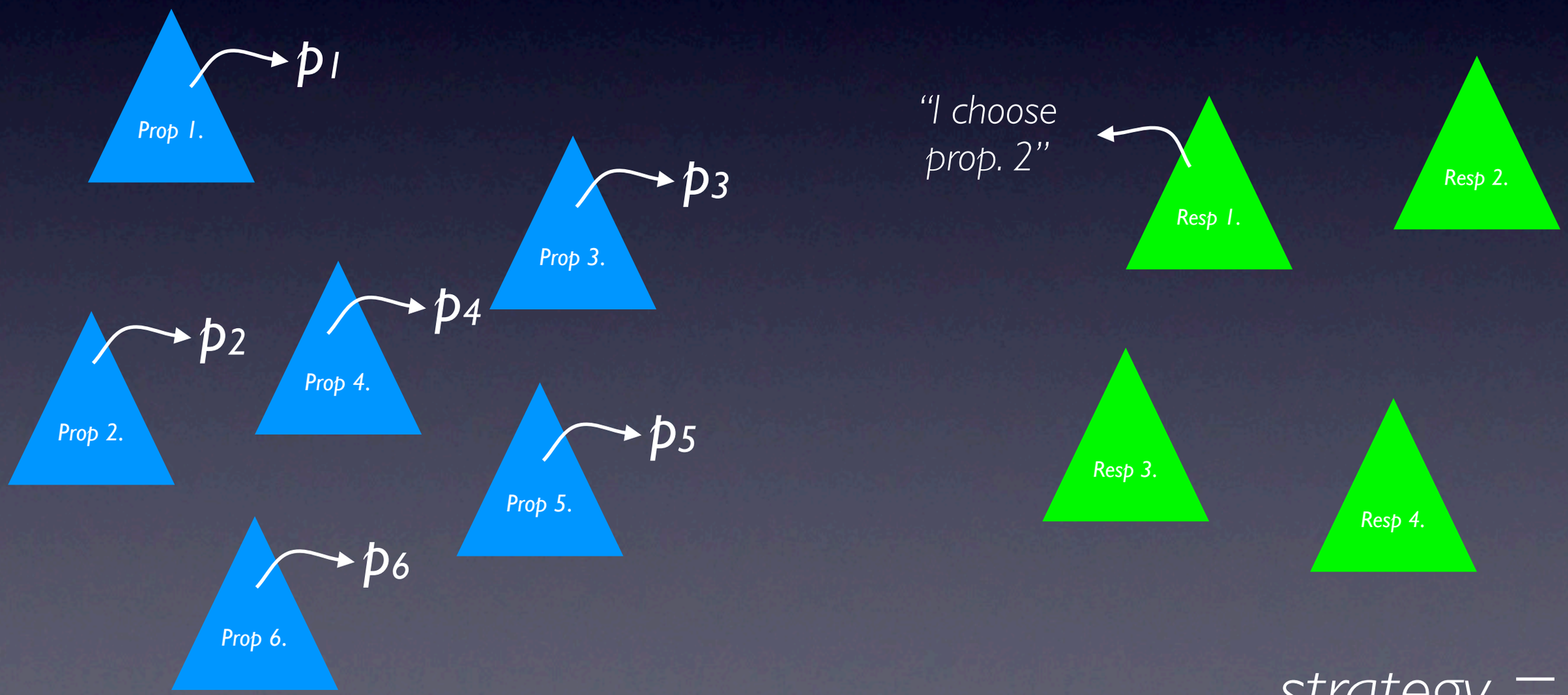
  (Nowak et al. 2000: footnote 14).

beyond pairwise bargaining

- when individuals have no other choice but to comply to their partner's request, the outcome of the interaction depends on the strategic relationship between partners
- what happens if individuals have other choices beyond acceptance or rejection?

a market of dictators

n_p proposers & n_r responders



strategy = p

assumptions

- proposers are genetically characterized by their offer p
- responders are perfectly informed
- the resource is perfectly divisible
- mutants are introduced one at a time (resident/mutant analysis)
- partner choice has no cost

market selection
does not lead to fairness

the *limiting* role takes all[1]

a market power-struggle has replaced
the strategic power-struggle

1. but see Noë & Hammerstein 1994

market selection does not lead to fairness

$n_p \leq n_r$

proposers

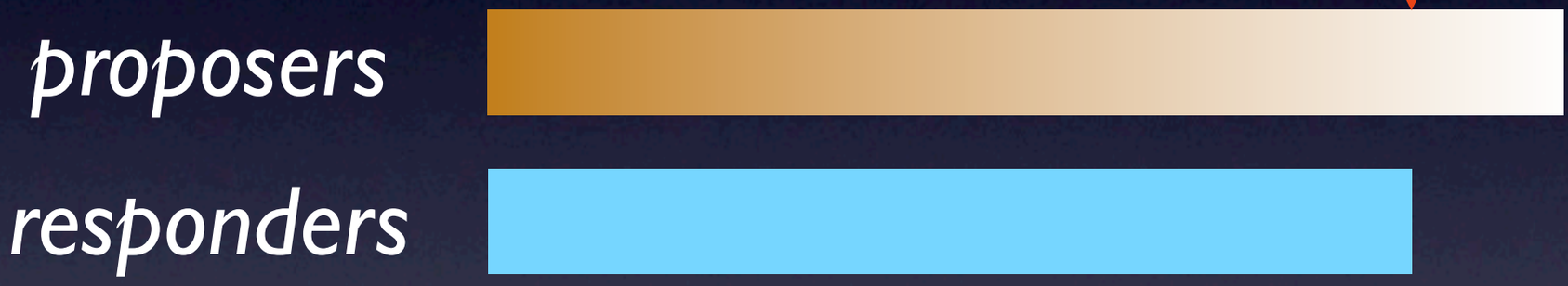
responders

the best strategy is to offer the minimum

ESS: proposers keep the whole resource

market selection does not lead to fairness

$n_p > n_r$

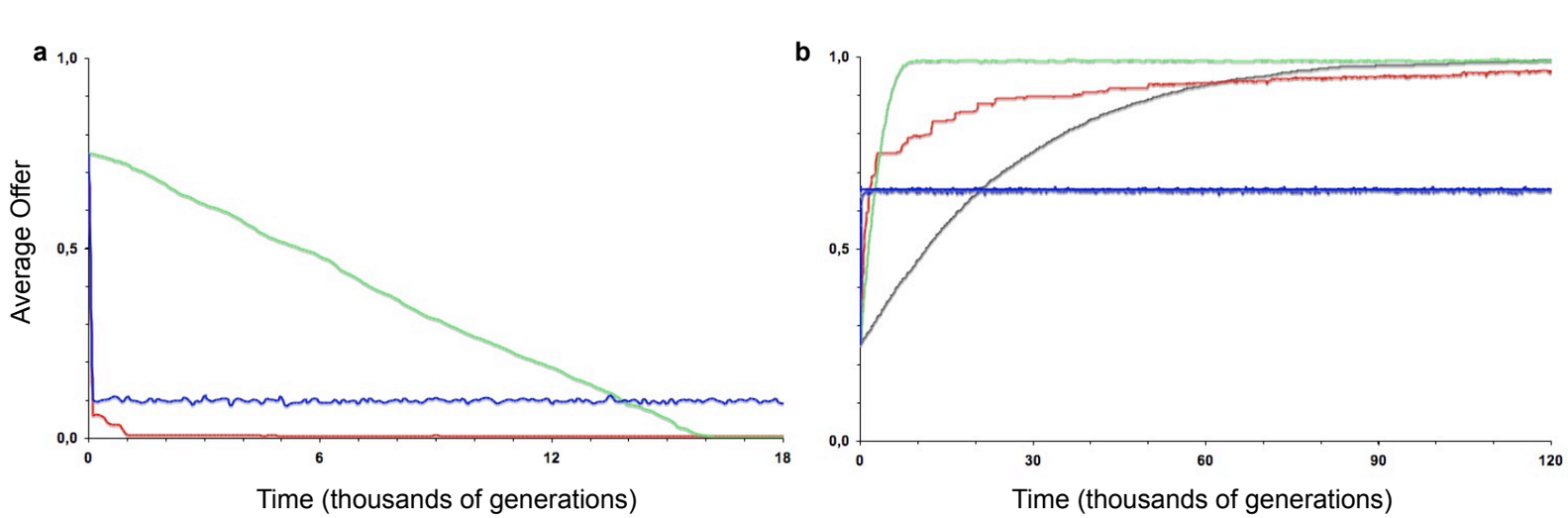


the best strategy is to offer
just a little bit more than the last paired proposer

ESS: *responders* keep the whole resource

individual based simulations

Figure 1



ecological feed-back

p could affect the effective frequency of proposers and responders

(i) because proposers/responders' demand of social interactions varies with p

(ii) because the actual density of proposers and responders vary with p

ecological feed-back

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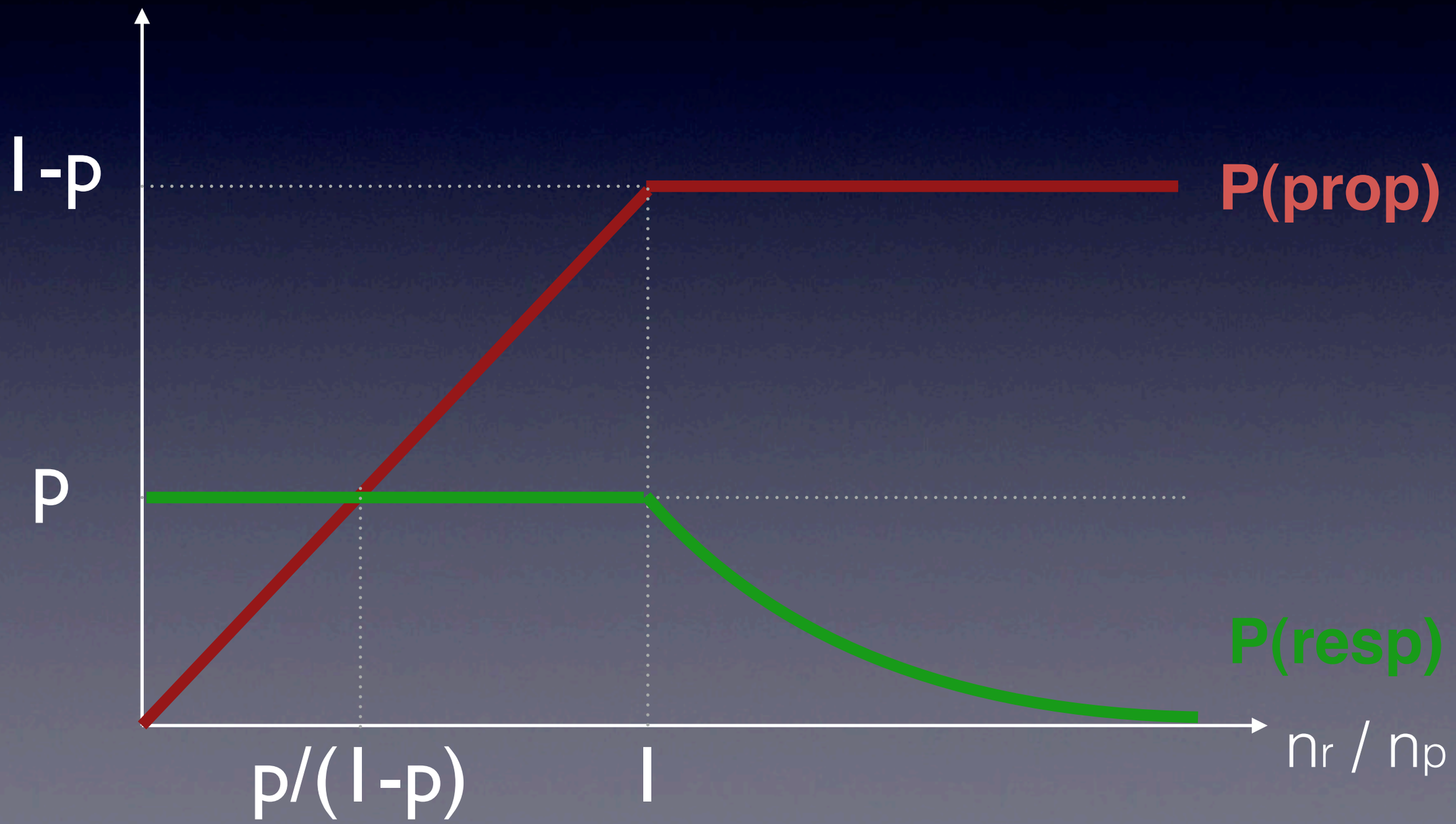
ecological feed-back



ecological feed-back

- assumption: the ideal free distribution of class frequency is reached very rapidly as compared to the rate of evolution
- the relative frequency of each class is always given by p/(1-p)
- resident / mutant analysis under this assumption

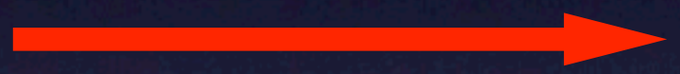
the evolution of fairness

the evolution of fairness

proposers offer less than one half

the evolution of fairness

proposers offer less than one half



proposers become more numerous

the evolution of fairness

proposers offer less than one half

proposers become more numerous

responders become limiting

the evolution of fairness

proposers offer less than one half

→

proposers become more numerous

↓

responders become limiting

←

market selection favors larger offers

the evolution of fairness

proposers offer less than one half

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the evolution of fairness

proposers
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proposers become limiting

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proposers offer more than one half

responders become more numerous

proposers become limiting

market selection favors lower offers

the evolution of fairness

proposers offer more than one half

responders become more numerous

proposers become limiting

market selection favors lower offers

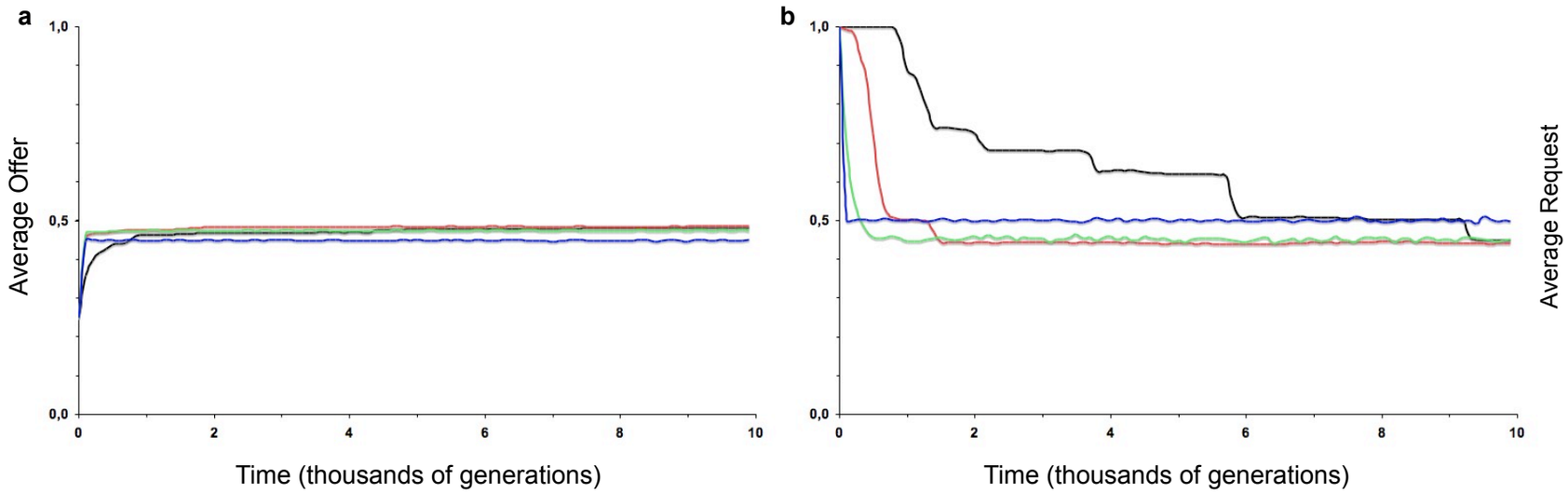
the evolution of fairness

the only equilibrium is reached when
proposers and *responders* gain exactly the same payoff

when the resource is divided in two equal shares

individual based simulations

Figure 2



conclusion

a fair division evolves when

- individuals can choose their partner
- the frequency of each trading-class is **freely** varying in function of their respective payoffs

conclusion

- there is an analogy with the evolution of sex-ratio except that, in sex-ratio, the division of benefits per interaction is constrained (50 / 50)
- in the present case, both the frequency of each class and the distribution of benefits evolve, and partner choice is driving the evolution toward 50 / 50

shortcomings

- the cost of choice is neglected
- partner choice is idealized
- individuals are from two distinct classes

a model of sequential pairing

a model of sequential pairing

random meeting

a model of sequential pairing

does interaction take place?

a model of sequential pairing

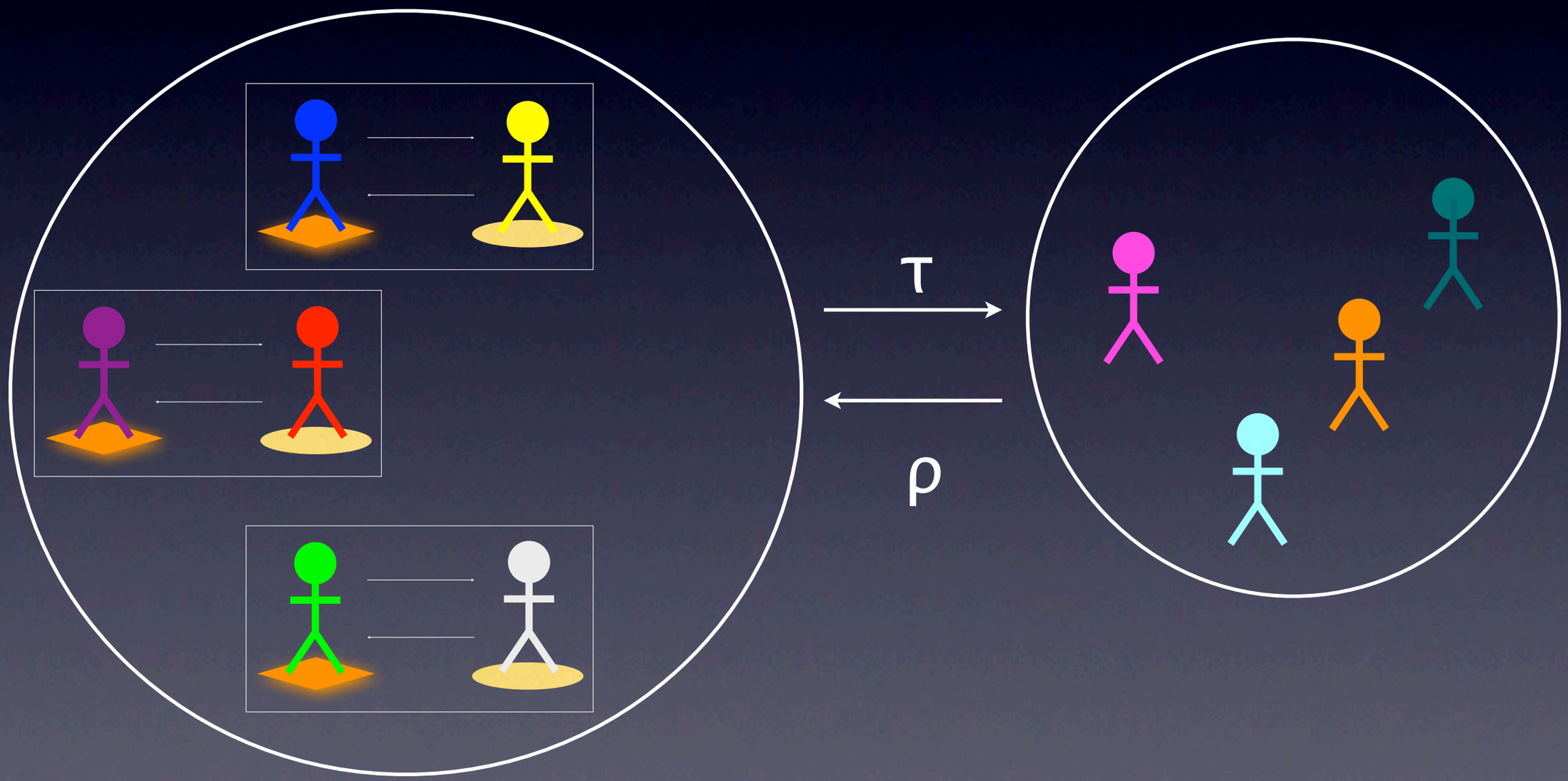
interaction lasts for a certain

a model of sequential pairing

interaction stops

the model

"social epidemiology"

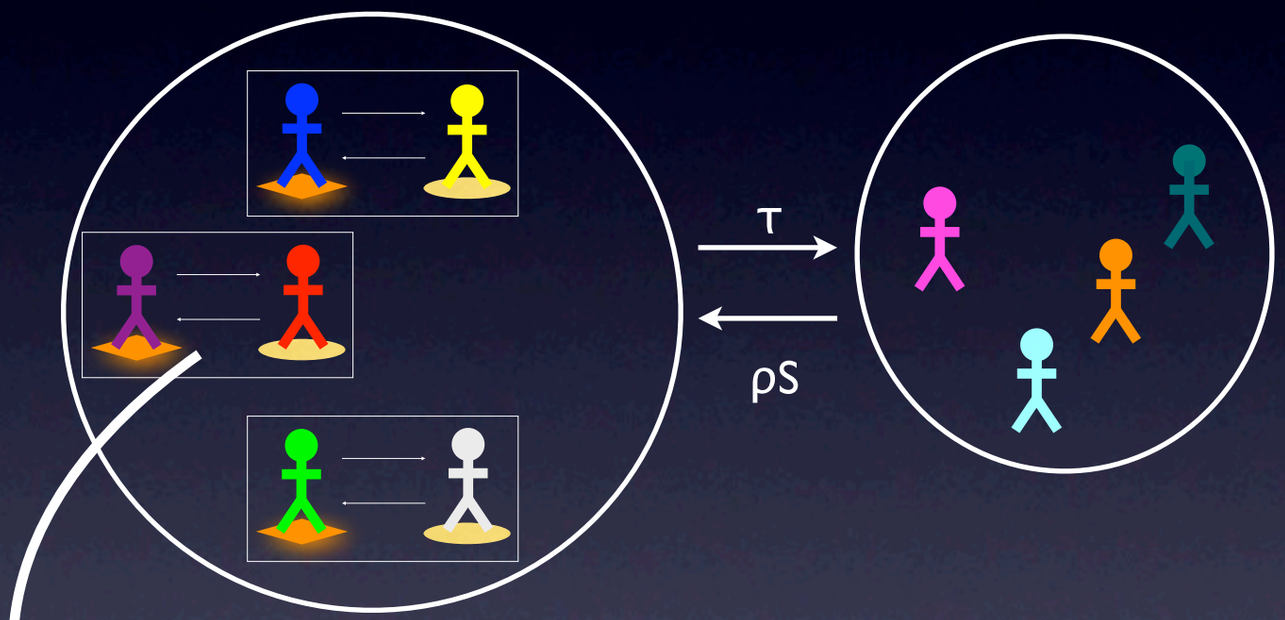


Interacting individuals, in density *I(t)*

Single individuals, in density *S(t)*

the model

"social epidemiology"



$$\dot{S} = \tau I - \rho S$$

Equilibrium density
of available partners
(with ρ = β)

$$\hat{S} = \frac{\tau}{\beta + \tau}$$

social opportunities

rate of social encounters β

$\beta << \tau$

One should
simply interact
as much as possible

$n \sim \beta$

$\beta >> \tau$

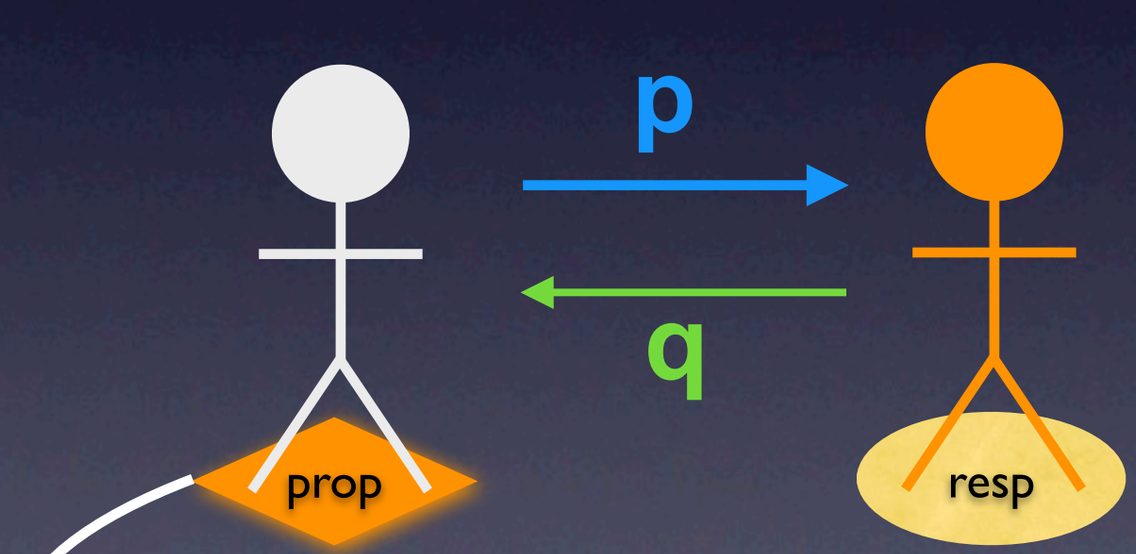
One should be picky
and maximize the gain
per each interaction

$n \sim \tau$

$$n = \frac{\beta\tau}{\beta + \tau}$$

the interaction

$P_{prop} = 1 - p$



$P_{resp} = p$

p and ***q*** jointly evolve

responder accepts if p > q

results

a resident is fixed with ***p*** and ***q***
and a rare mutant is introduced

Payoff of the resident $$G = \frac{\beta/2 + \sigma\tau}{\beta + \tau}$$

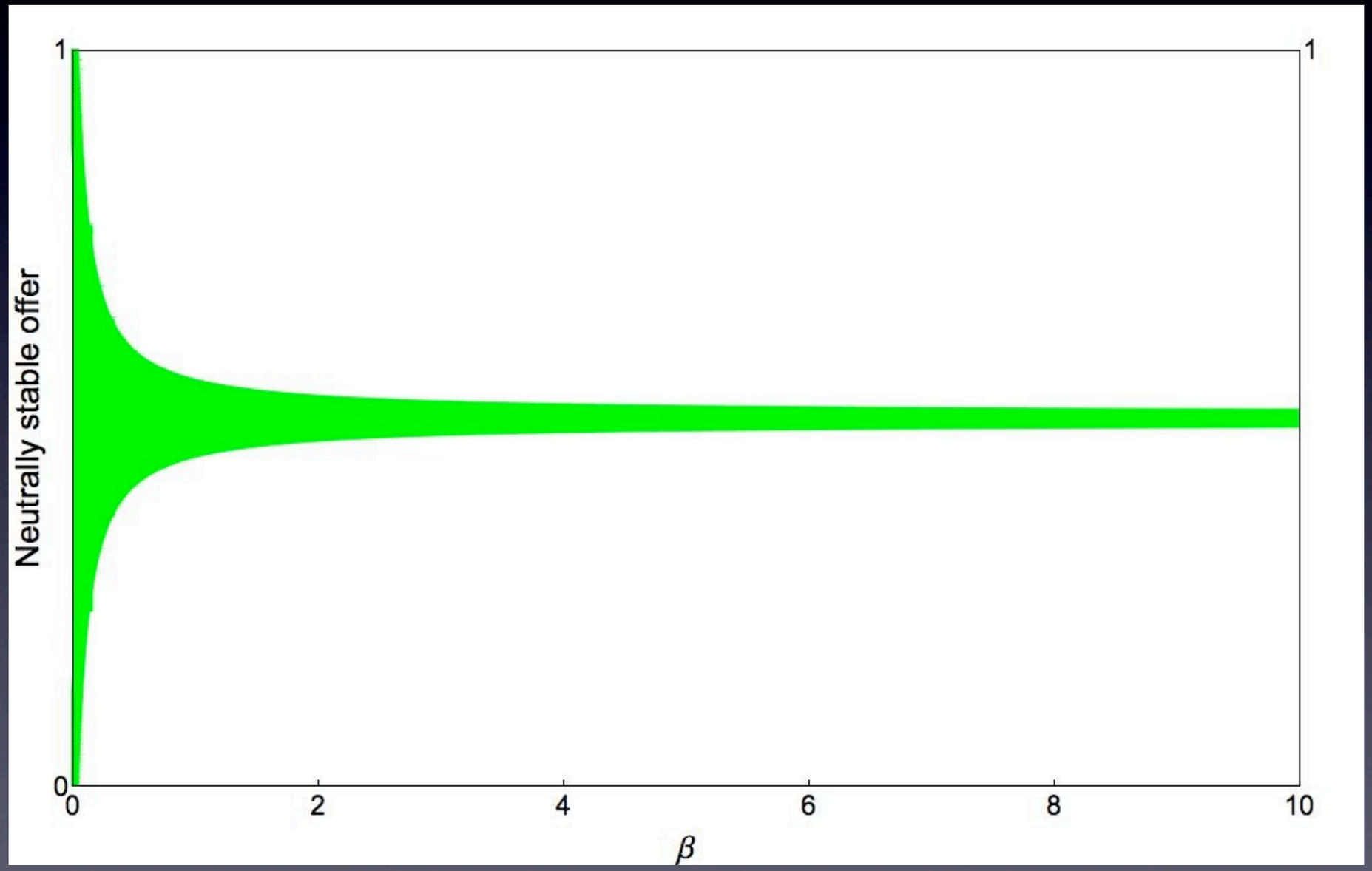
Payoff of the mutant $$G' = \frac{\beta\alpha' g' + \sigma\tau}{\beta + \tau}$$

results

- an ESS must have p = q
- a mutant with q' > q cannot invade iff p > p*
- a mutant with p ' < p cannot invade iff p < 1 - p*
- other mutants cannot be favored

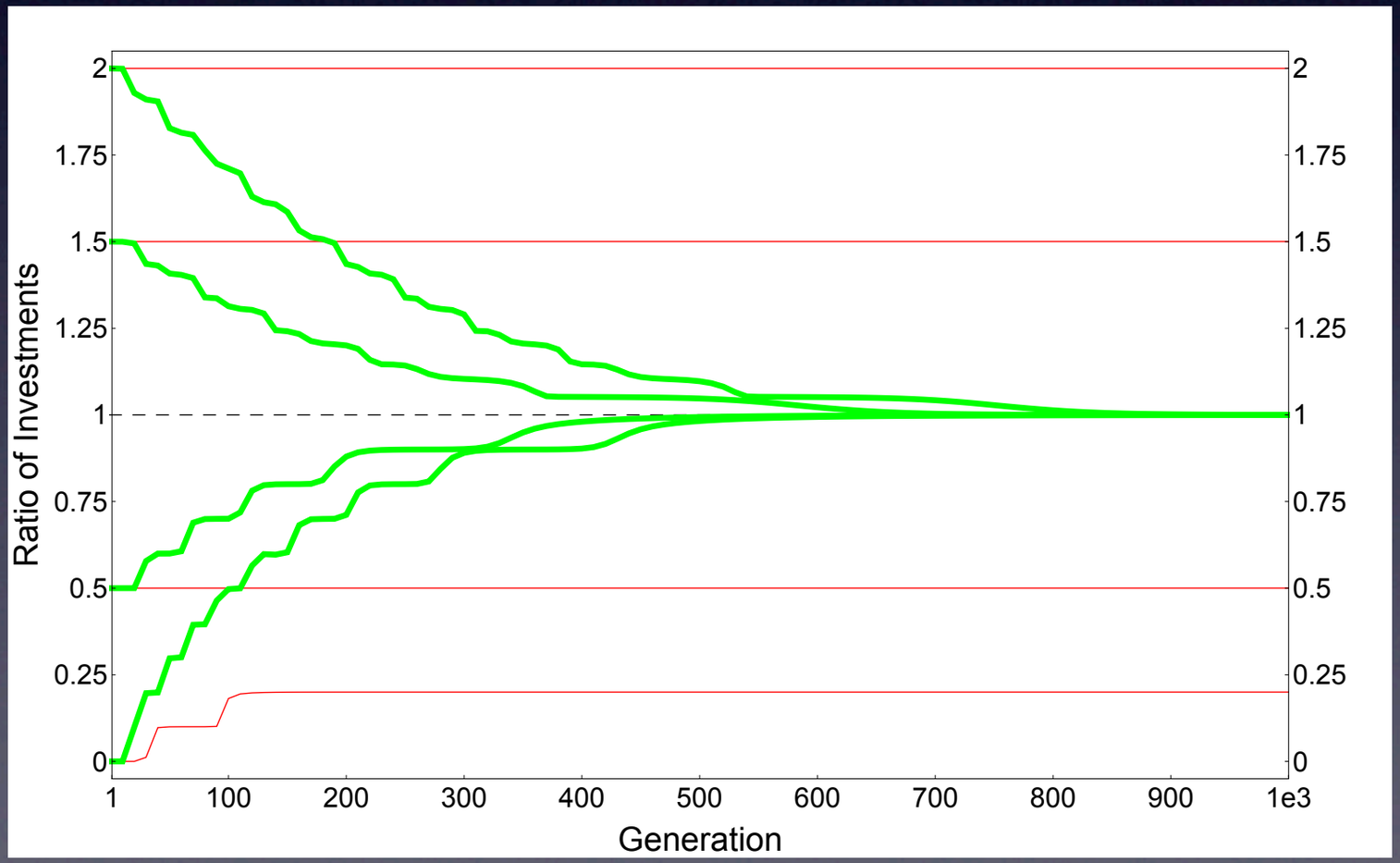
$$p^* = \frac{\beta/2\tau + \sigma}{\beta/\tau + 1}$$

results



results

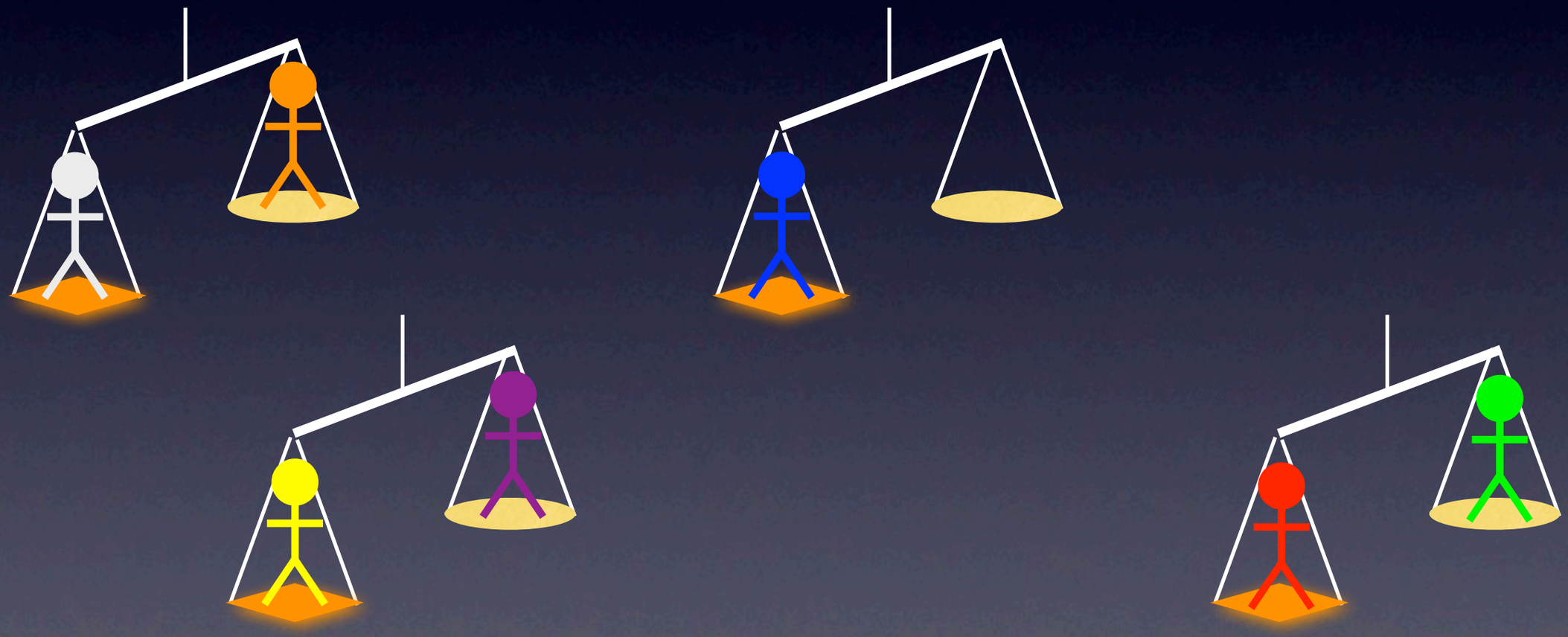
numerical resolutions of analytical results



without partner change ➜
multiple arbitrary equilibria
(**red**)

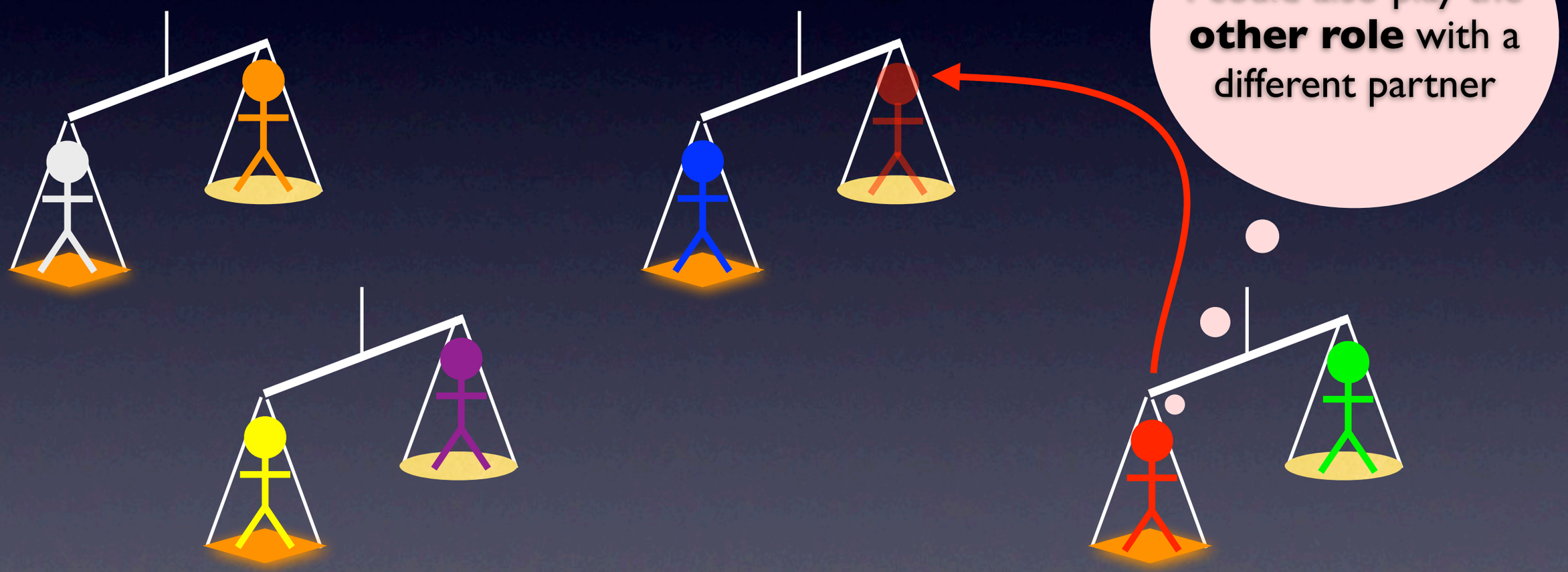
with partner change ➜
fairness is the only possible
equilibrium (**green**)

interpretation



analogy with reproductive skew theory (Vehrencamp 1983)

interpretation

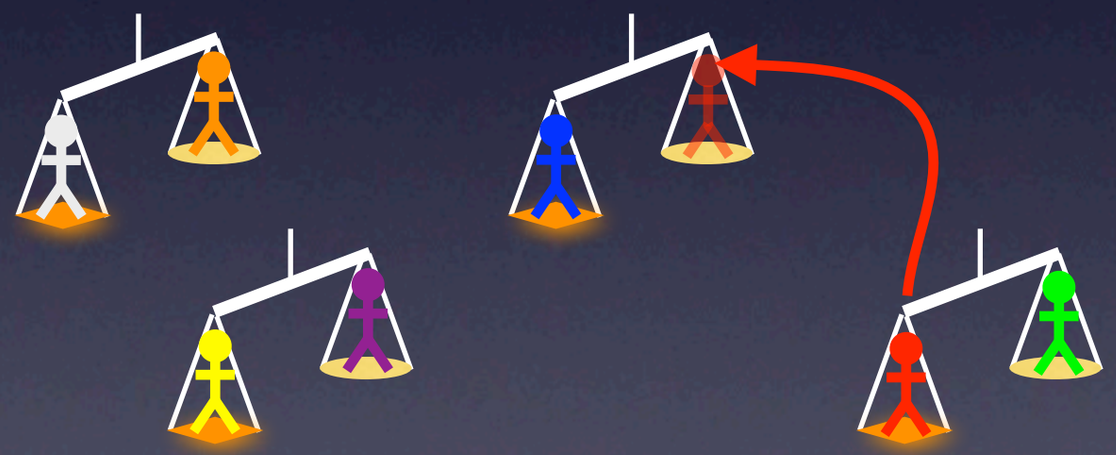


analogy with reproductive skew theory (Vehrencamp 1983)

interpretation

interpretation

a local bargaining asymmetry between two players
is not sufficient to allow for an asymmetric outcome



perspectives

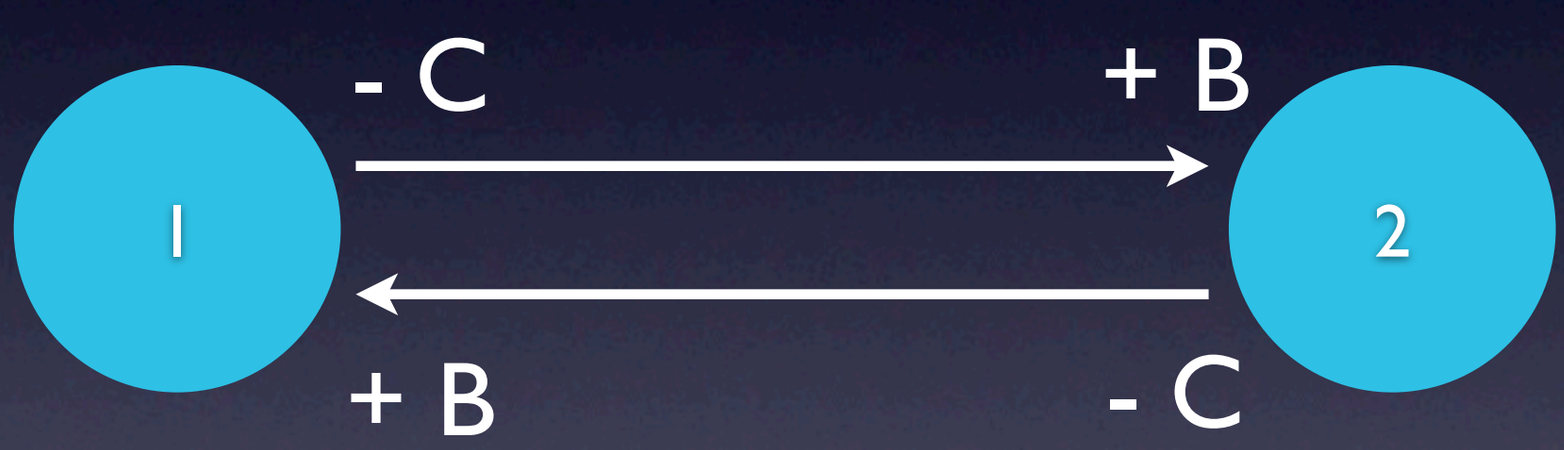
- fairness even when individuals differ durably in their competitive abilities
- fairness with varied outside options: accounting for merit
- fairness with variable investment: accounting for the proportionality principle

general (but vague) conclusion

when the individuals in an interaction are e*qual*, not in the sense that they have the same bargaining power or play the same role within the interaction, but in the more important sense that they have the same average opportunities outside the interaction, they should receive the **same gain** per unit of investment

resource allocation theory applied to social life: the marginal benefit of each unit of resources invested in various social activities should be equal in equilibrium

cooperation: existence and nature



cooperation is *possible* with reciprocity...

... but is not certain

- cooperation can be stabilized by reciprocity
- but anything else can also be stabilized
  (this is called the folk theorem)

the multiplicity of equilibria

an example: **Grim**

always cooperate
unless oneself or one's partner has defected in the past

the multiplicity of equilibria

an example: **Grim**

always cooperate
unless oneself or one's partner has defected in the past

C C C C C C C C C C C C C C C C C C C C

Grim stipulates maximal and fair cooperation

the multiplicity of equilibria

an example: **Grim**

always cooperate
unless oneself or one's partner has defected in the past

C C C C C C C C C C C C C C C C
C C C C C C C C C C C C C C C C

Grim stipulates maximal and fair cooperation

Grim is a Nash equilibrium, a neutrally stable strategy,
a Subgame perfect equilibrium, a limit ESS.

the multiplicity of equilibria

but other strategies can be stable,
differing with regard to

(i) the intensity of cooperation

(ii) the fairness of cooperation

the amount of cooperation

here is an other example: **pair-Grim**

*always cooperate on **pair** days*

*unless someone has defected in the past on a **pair** day*

C D C D C D C D C D C D C D C D
C D C D C D C D C D C D C D C D

pair-Grim is a Nash equilibrium, a neutrally stable strategy,
a Subgame perfect equilibrium, a limit ESS.

the amount of cooperation

impair-Grim

D C D C D C D C D C D C D C D C
D C D C D C D C D C D C D C D C

impair-Grim is a Nash equilibrium, a neutrally stable strategy,
a Subgame perfect equilibrium, a limit ESS.

the amount of cooperation

monday-Grim

C D D D D D D C D D D D D D C D
C D D D D D D C D D D D D D C D

monday-Grim is a Nash equilibrium, a neutrally stable strategy,
a Subgame perfect equilibrium, a limit ESS.

the fairness of cooperation

- in all real life cases partners differ,
  if only with regard to an arbitrary variable
- this makes still other strategies possible

the fairness of cooperation

asymmetric-Grim-1

C C C C C C C C C C C C C C C C
C D C D C D C D C D C D C D C D

asymmetric-Grim-1 is a Nash equilibrium, a neutrally stable strategy,
a Subgame perfect equilibrium, a limit ESS.

the fairness of cooperation

asymmetric-Grim-2

C D D C D D C D D C D D C D D C
C C C C C C C C C C C C C C C C

asymmetric-Grim-2 is a Nash equilibrium, a neutrally stable strategy,
a Subgame perfect equilibrium, a limit ESS.

equilibrium selection

- reciprocity (in a large sense)
  seems to work pretty well, in our social life,
  to promote fairness and cooperation
- yet, what game theory shows is that
  it could also promote anything else
- what mechanism selects among equilibria?

cultural group selection

*"... the right take-home message from all this theoretical work is that the **genetic** evolution of cooperation via direct reciprocity is not a particularly robust solution"*

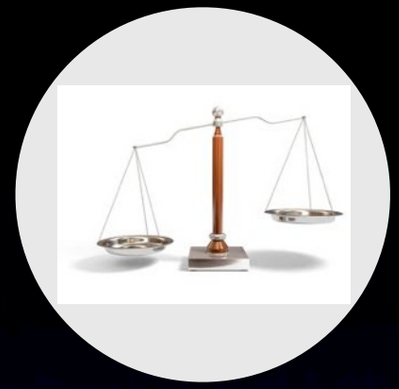
*"The combinatorial explosion is solved in humans through **cultural** transmission"*

Henrich and Henrich 2007 pp. 54-55

cultural group selection

"Systems of reciprocity and reputation can stabilize a vast range of behaviours [...]. Rapid ***cultural*** *adaptation can then lead to persistent differences between local social groups, , and then competition* ***between groups*** *leads to the spread of behaviours that enhance the competitive ability of groups."*

Boyd and Richerson 2009 Phil.Trans. R. Soc. B 364



diversifying
cultural evolution
within groups

group selection

an alternative solution

an alternative solution

Partner control

an alternative solution

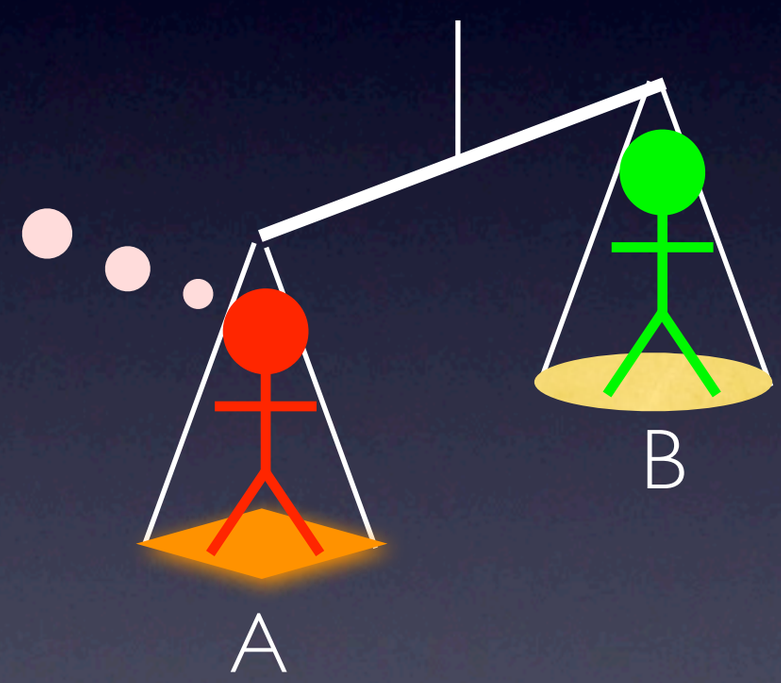
Partner control

vs.

Partner choice

partner control

will I gain more
than if I was **alone**?



weak constraint ➜ indeterminacy of the ESS

partner choice

stronger constraint ➜ less indeterminacy

partner choice

when individuals can choose/change partner

- local asymmetries are evolutionarily unstable
- the most cooperative strategies are favored
  (Roberts 1998; Aktipis 2006; McNamara et al. 2011)

partner choice

the multiplicity of equilibria, an argument in favor of cultural evolution, is an artifactual consequence of the emphasis on partner control models

thank you!

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