When more of the same is better

Is there a global brain?

When does a group of cooperating individuals solve a problem more efficiently than the individuals working in isolation?

Does diversity matter?

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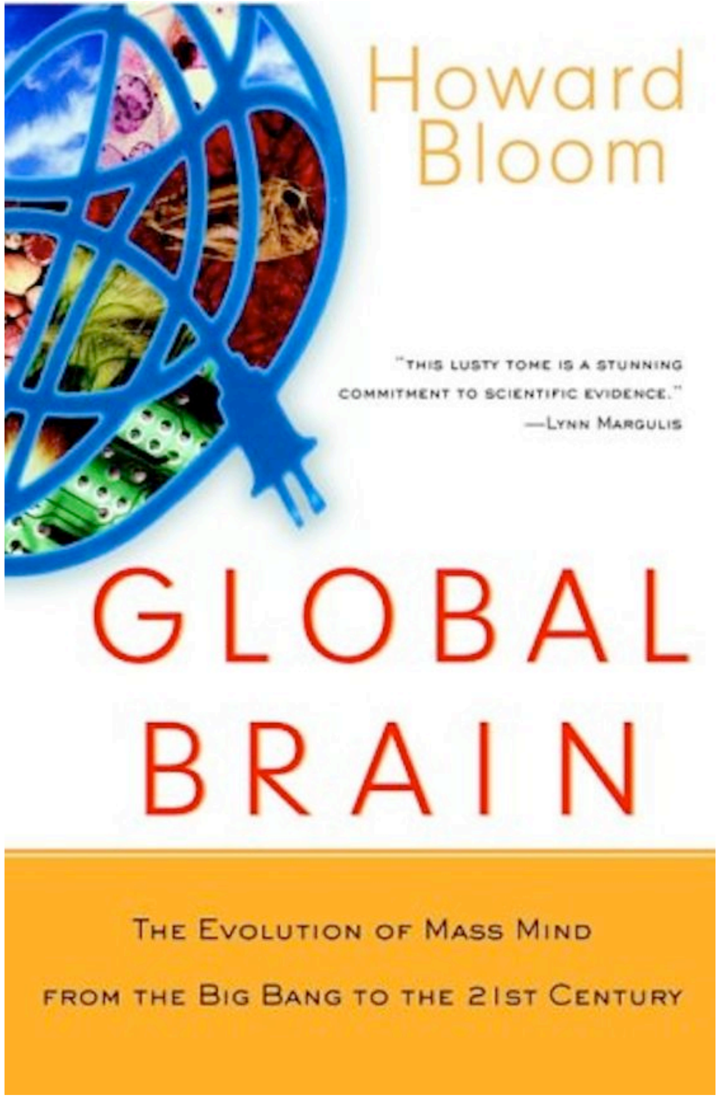
Outline

- Introduction
- Task: Kauffman´s NK fitness landscape
- Independent search
- Cooperative search
- Conclusion

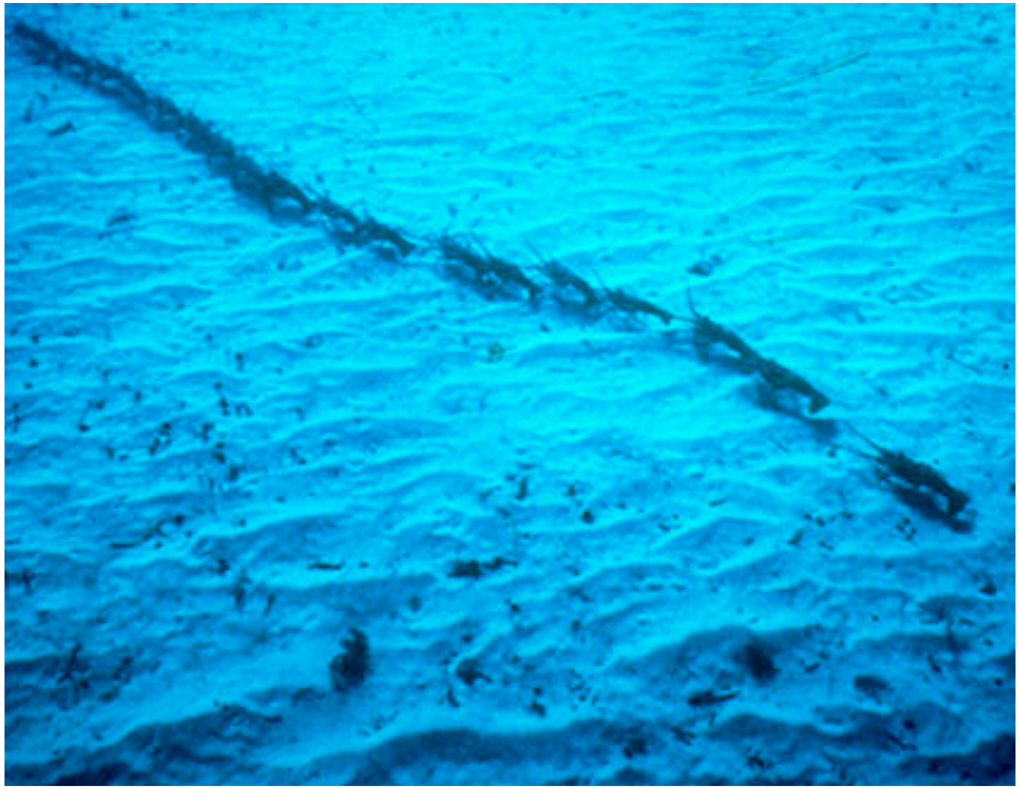
this is not about the wisdom of crowds



"Imitative learning acts like a synapse, allowing information to leap the gap from one creature to another."

Spiny lobsters (*Panulirus argus*) migration

Imitation



These mass migrations may last several days with lobsters walking both night and day.

Hierarchy

Lobsters love to fight and female lobsters
adore the most aggressive one in the bunch.

Task: find the global maximum of NK fitness landscapes

Kauffman & Levin (1987)

Binary strings of length N: $x = (x_1, x_2, \ldots, x_N)$ $x_i = 0,1$

solution space size 2^N

Fitness function:

$$\Phi(x) = \frac{1}{N}\sum_{i=1}^{N}\phi_i(x)$$

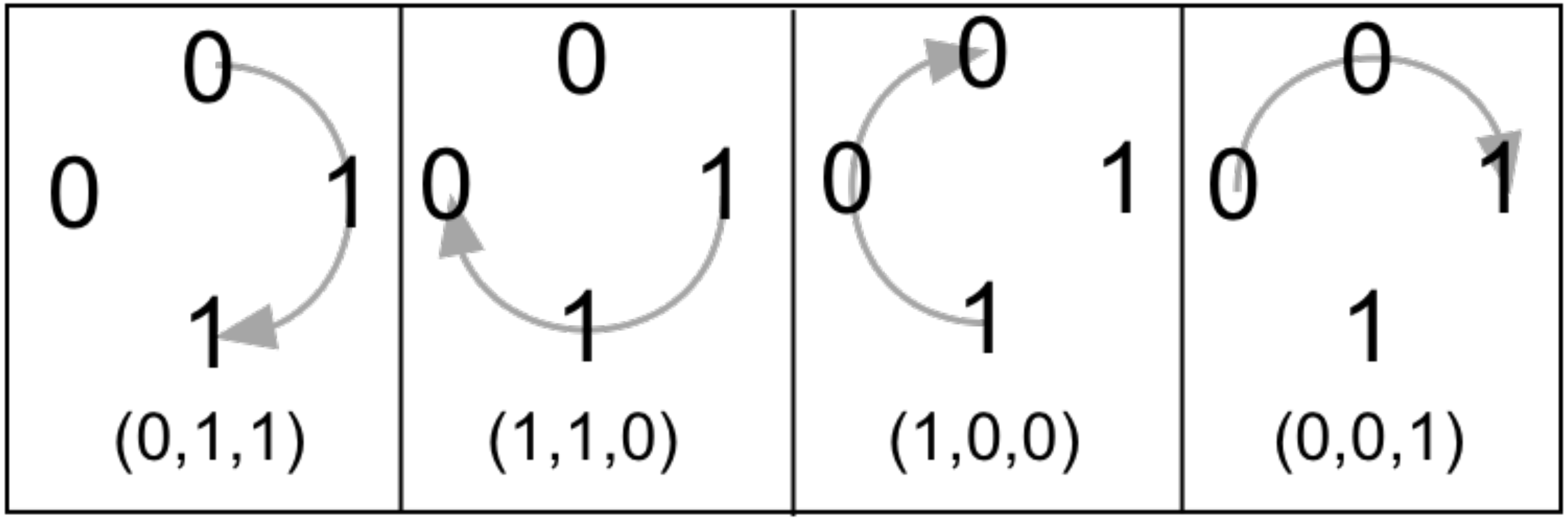
$$\phi_i(x) = \phi_i(x_i, x_{i+1}, \ldots, x_{i+K})$$

random number in [0,1]

depends on ***K*** neighbors

Example:

N=4, *K*=2

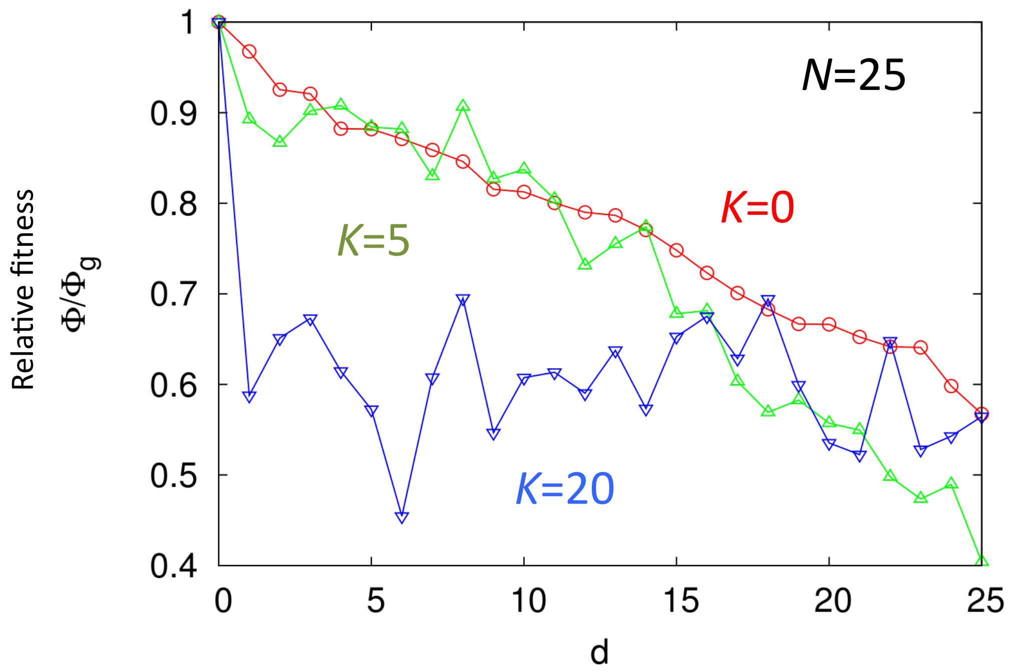


$$\Phi(0,1,1,0) = \frac{1}{4}\left[\phi_1(0,1,1) + \phi_2(1,1,0) + \phi_3(1,0,0) + \phi_4(0,0,1)\right]$$

$$\left.\begin{aligned} \phi_1(0,1,1) &= 0.3 \\ \phi_2(1,1,0) &= 0.2 \\ \phi_3(1,0,0) &= 0.5 \\ \phi_4(0,0,1) &= 0.1 \end{aligned}\right\}$$ random in [0,1]

$$\Phi(0,1,1,0) = 0.275$$

K determines the ruggedness of the landscape



Hamming distance to global maximum

Correlation between neighbor strings = $1 - (K+1)/N$

- 1-1/N for *K*=0 — smooth
- 0 for *K*=*N*-1 — REM

Model v1.0 - independent search

Agents are **strings**

Group size M

that walk in the solution space by flipping bits at random

(1,0,1,0,0,0,1,1,1) before

(1,0,1,1,0,0,1,1,1) after

until some string hits the global maximum.

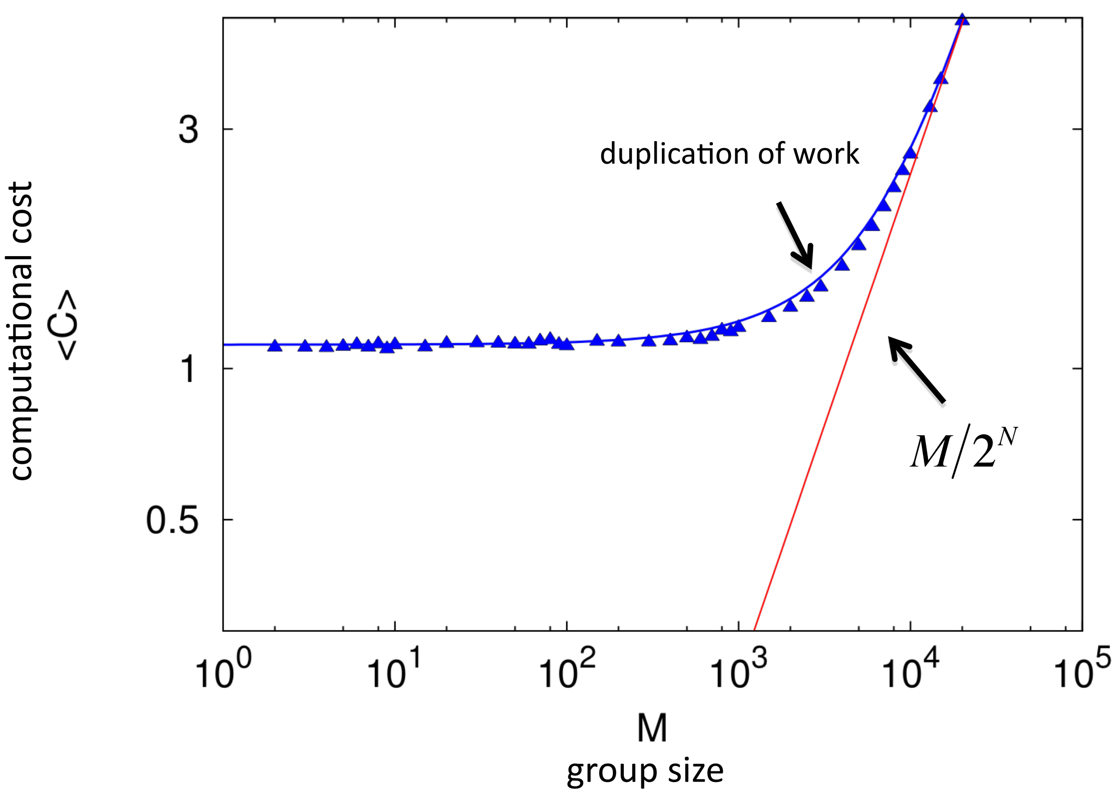
Δt=1: all M agents are updated

t^* time to find the solution

$$C = Mt^* / 2^N$$

computational cost

Results for the independent search



N=12

Any *K*

$$\langle C \rangle = \frac{M}{2^N\left[1-(\lambda_N)^M\right]}$$

$1-\lambda_{12} \approx 1/4545$

λ_N is the second largest eigenvalue of **T** stochastic tridiagonal matrix

$$T_{ij} = (1 - j/N)\delta_{i,j+1} + j/N\,\delta_{i,j-1}$$

index i is number of 1s

$$T_{i0} = \delta_{i,1} \qquad T_{iN} = \delta_{i,N}$$

Model v2.0 - imitative learning search

model agent: the highest fitness string in the group

(**1**,**1**,1,1,1,1,**1**,**1**,**1**,**1**)

different bits

target agent: the string to be updated

(0,0,1,1,1,1,0,0,0,0)

choose one of the 6 different bits of the model string and assimilate it.

resulting string after update

(0,0,1,1,1,1,0,0,0,**1**)

Dynamics

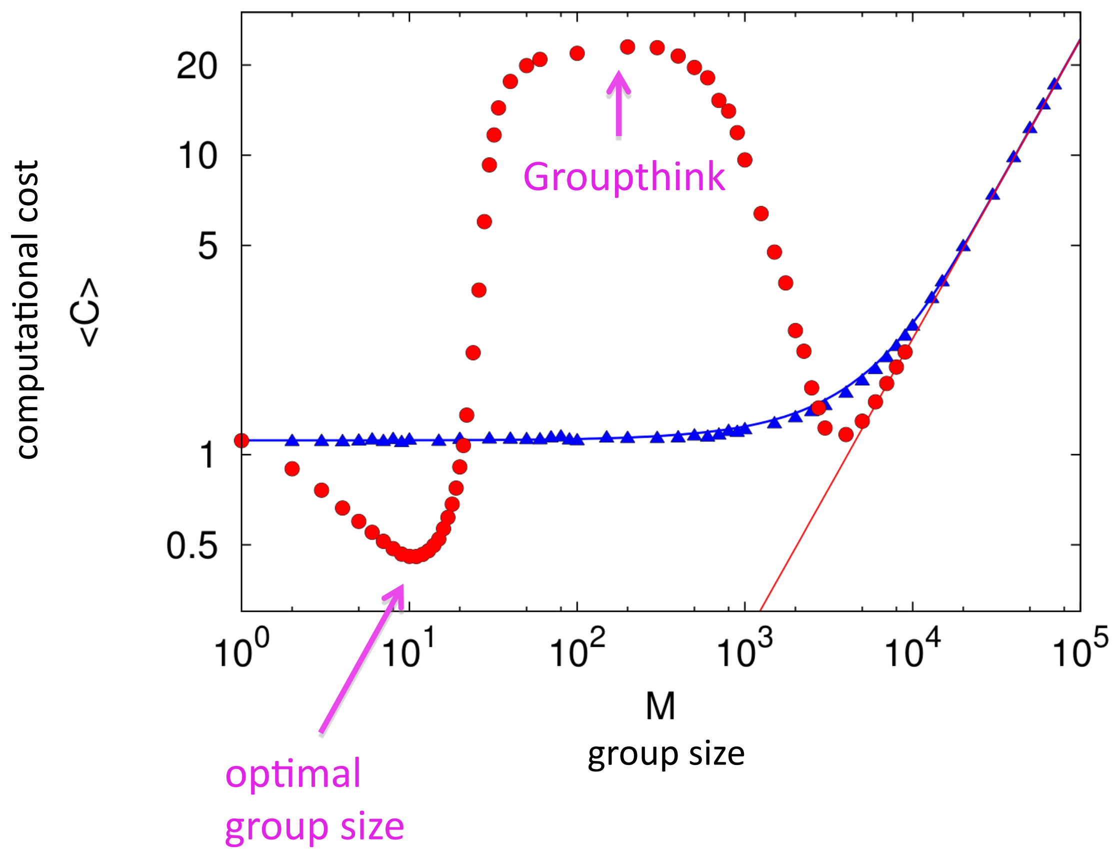
0. Initialize population randomly, evaluate fitness, determine model string.
1. Select one agent at random *without replacement*
2. **Imitate the model string with probability *p* or flip bit at random with probability 1-*p*.**
3. Stop if global maximum is found
4. Update model string
5. Return to 1 till all *M* agents are updated
6. Increment time step *t* by one unit: *t* = *t*+ 1

what if the target agents is the model or one its clones?

$$p \in [0,1]$$

imitation probability or copy propensity

Results for the cooperative search



landscape parameters

N=12
K=4
2^{12}= 4096

imitation probability

p=0.5

fully connected network

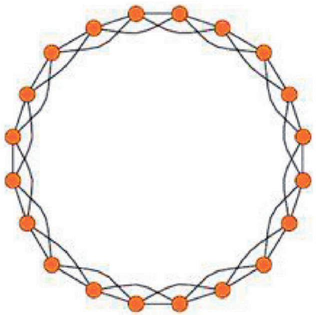
Groupthink: psychological studies of policy decisions and fiascoes (1982)

occurs when everyone in a group starts thinking alike, which happens when people put unlimited faith in a talented leader (e.g., JFK in the case of the Bay of Pigs and the model strings, in our case).

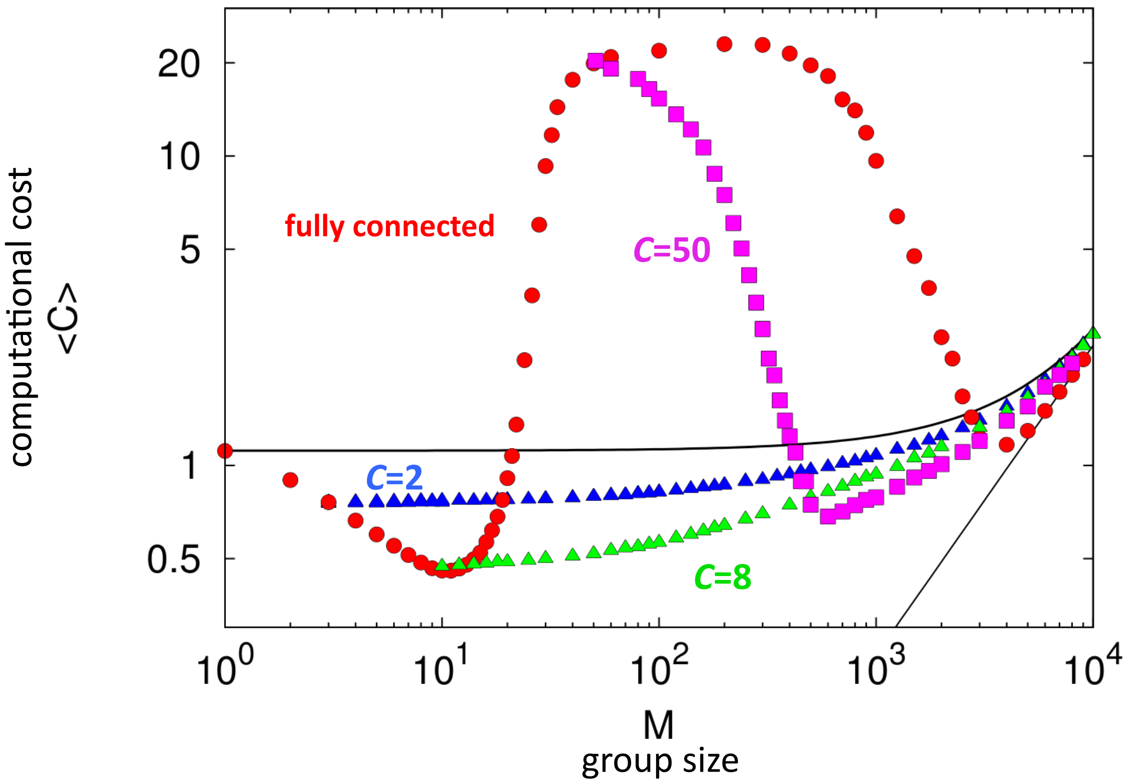
How to avoid Groupthink (local maxima)?

Decrease or slow down the influence of the leader!

Influence network of an agent is limited to its neighbors.



ring with connectivity *C*=4



optimal organization is a **small fully connected** group.

How about diversity?

Assume the copy propensity *p* is different for each agent!

$$H(p) = \delta(p - 0.5)$$

$$B(p) = \frac{1}{2}\delta(p) + \frac{1}{2}\delta(p - 1)$$

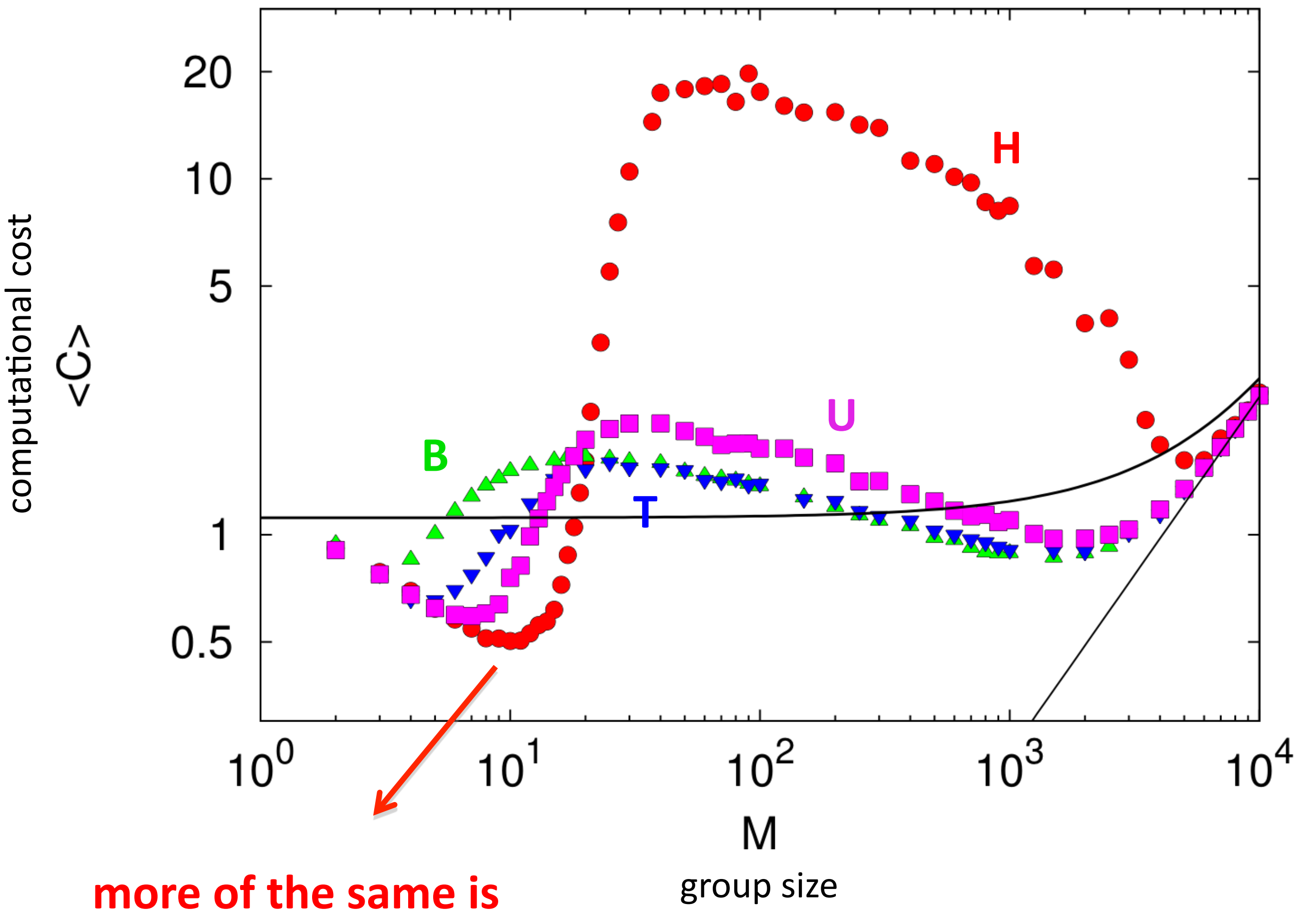
$$T(p) = \frac{1}{3}\delta(p) + \frac{1}{3}\delta(p - 0.5) + \frac{1}{3}\delta(p - 1)$$

$$U(p) = 1 \qquad p \in [0,1]$$

diversity

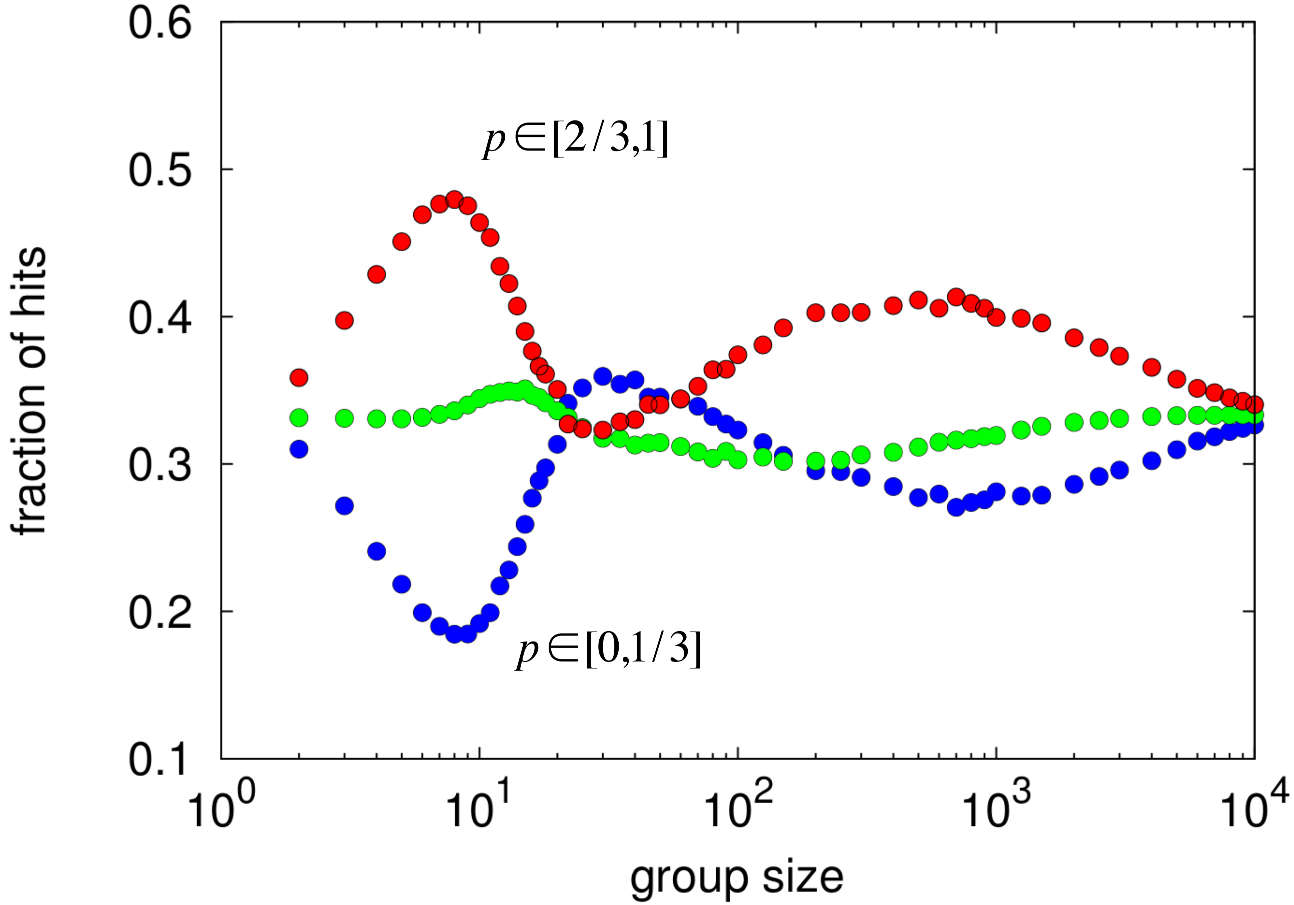
$$\langle p \rangle = 0.5$$

fully connected network



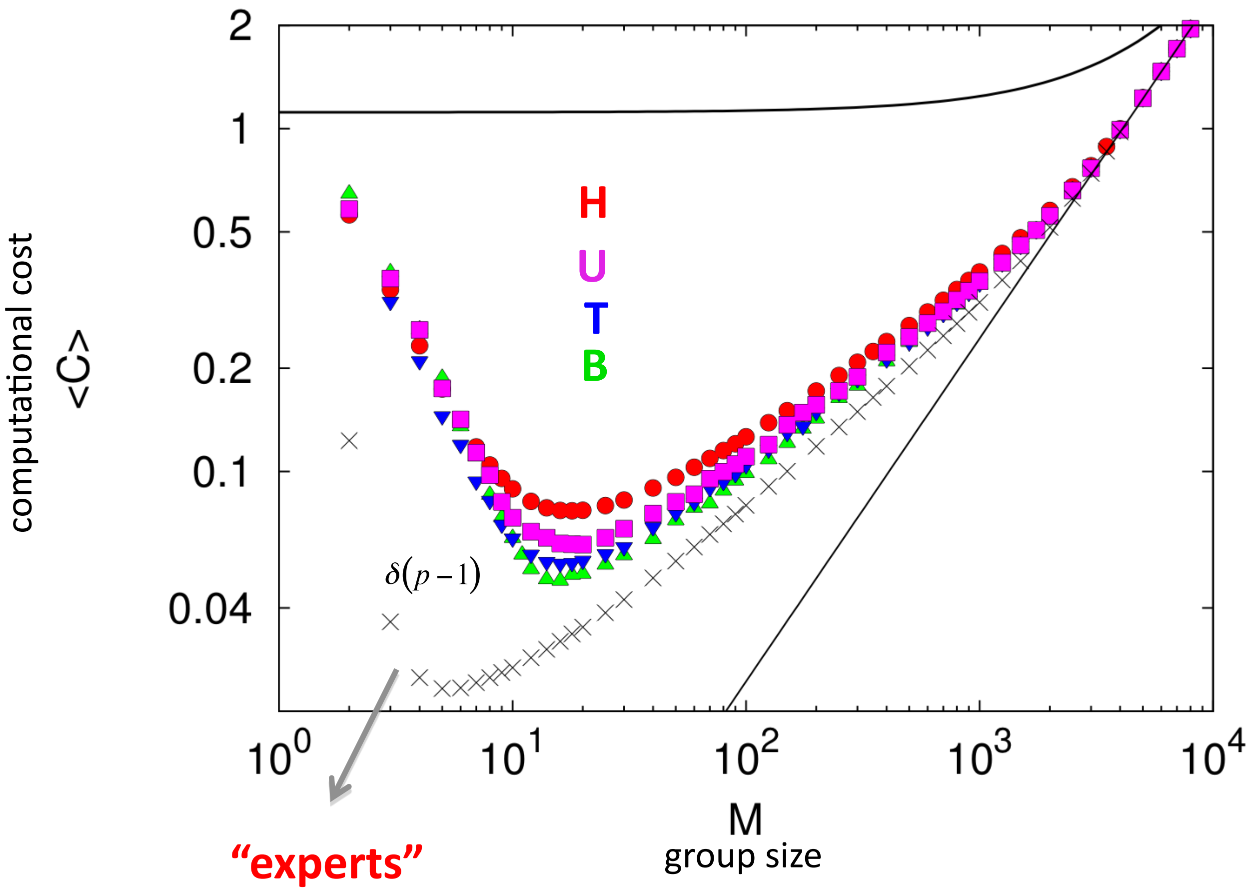
more of the same is better!

Who is more likely to hit the solution?



Uniform distribution

Easy task: no local maxima

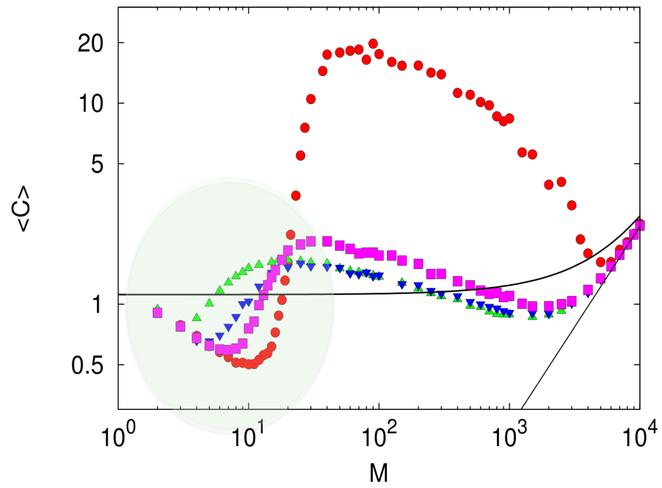


landscape parameters

N=12
K=0
2^{12}= 4096

Clichés

- More isn't (always) better
- More of the same can be better (but I don't know why)



Group size of social animals?

Thanks!

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