

Caffè Scienza su
Computer e complessità

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Cos'è la complessità?
(per un fisico)

Cos'è la complessità? (per un fisico)

- **MICRO:**
 - molti costituenti (semplici)
 - interaz. / scambio informaz.
- **MACRO:**
 - molti "stati" globali
 - robusti a perturbaz. random
 - cambiano sotto perturbaz. specifica

MORE IS DIFFERENT

(P. W. Anderson, 1972)

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(P. W. Anderson, 1972)

fenomeno collettivo	componenti semplici
fisica atomica	particelle elementari
chimica	fisica atomica
biologia molecolare	chimica
biologia della cellula	biologia molecolare
...	...
psicologia	fisiologia
scienze sociali	psicologia

Esempi di sistemi complessi

Fenomeni sociali



- reti interazione sociale
- finanza / economia
- votazioni / formazione consenso



Esempi di sistemi complessi



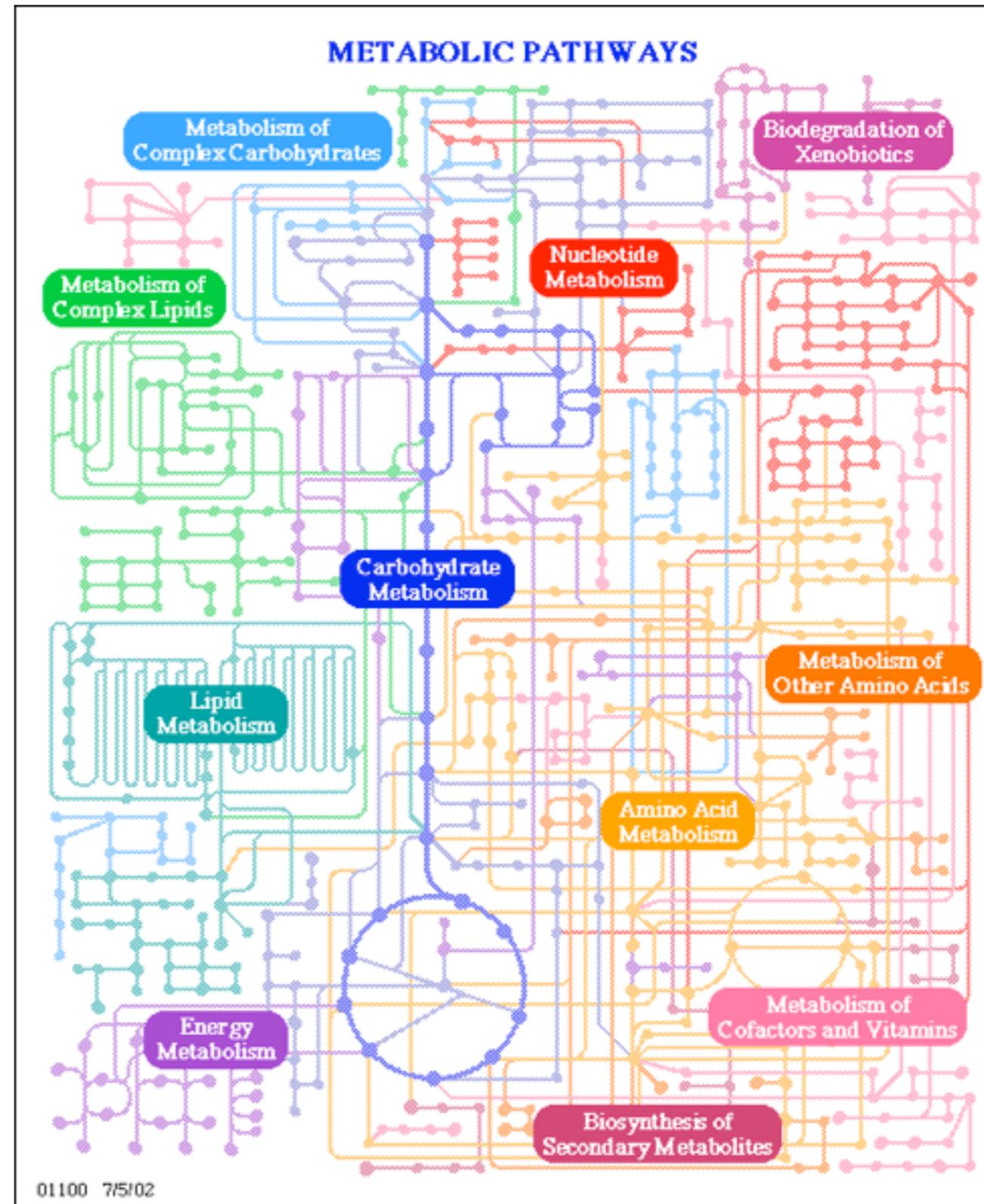
Teoria delle reti

- WWW, trasporti (epidemie)
internet, scambi commerciali
- eterogeneità, code "pesanti"
- strutture locali (communities)
- topologia \leftrightarrow crescita dinamica

Esempi di sistemi complessi

Reti biologiche

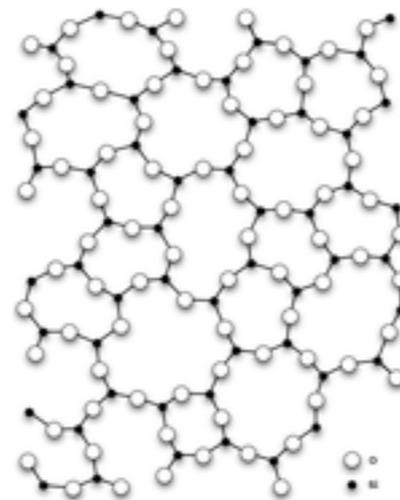
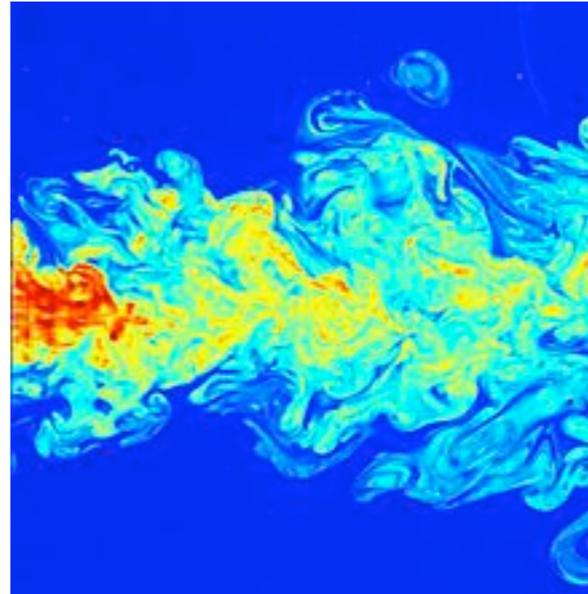
- ecologiche
- neuronali
- metaboliche
- espressione genica



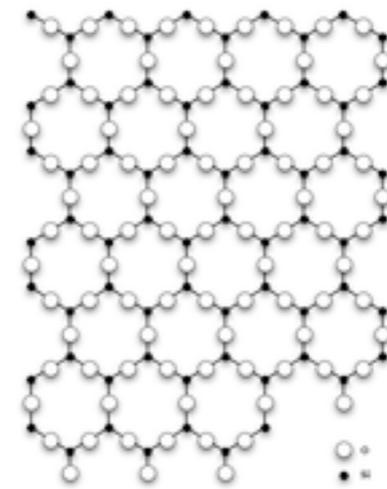
Esempi di sistemi complessi

Fisica della materia

- fluidi turbolenti
- vetri
- spin glasses

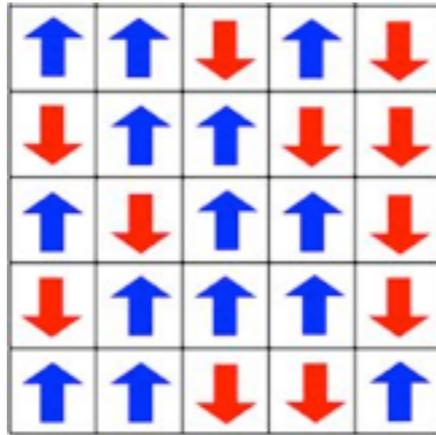


stato amorfo

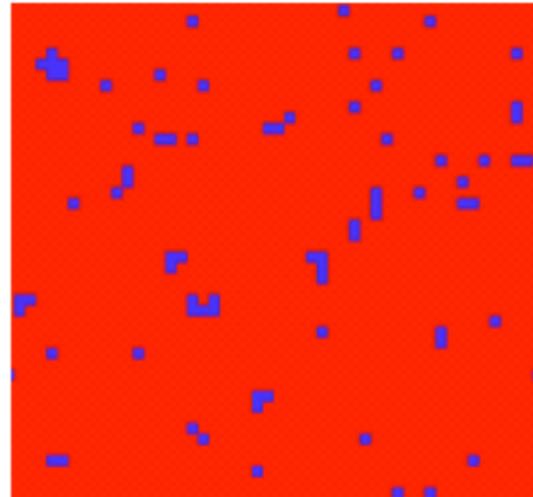


cristallo

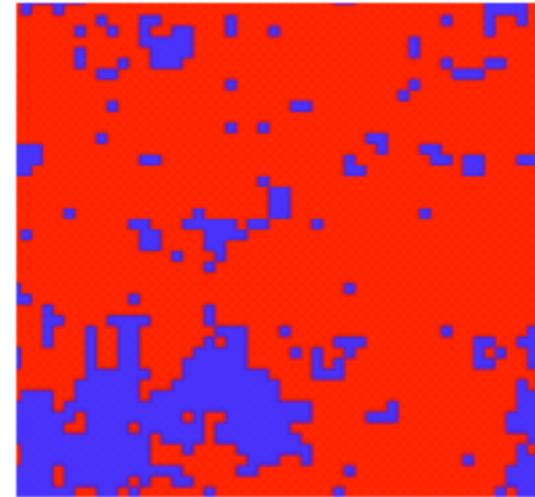
Modello di Ising



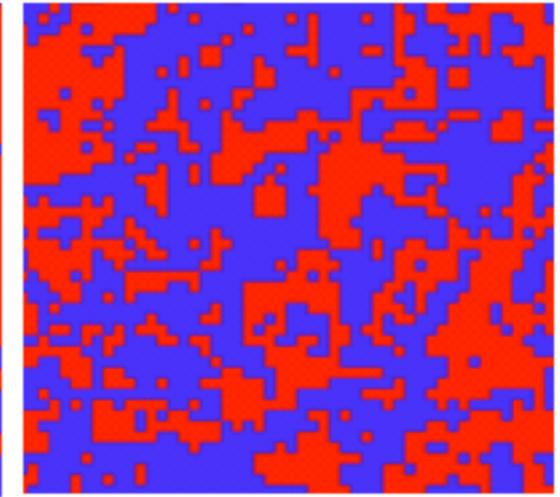
$T=2 \quad J/k_B$



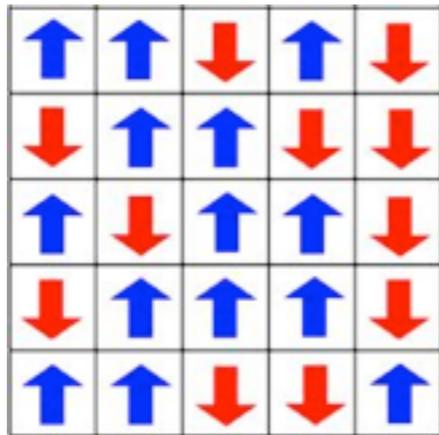
$T=T_c$



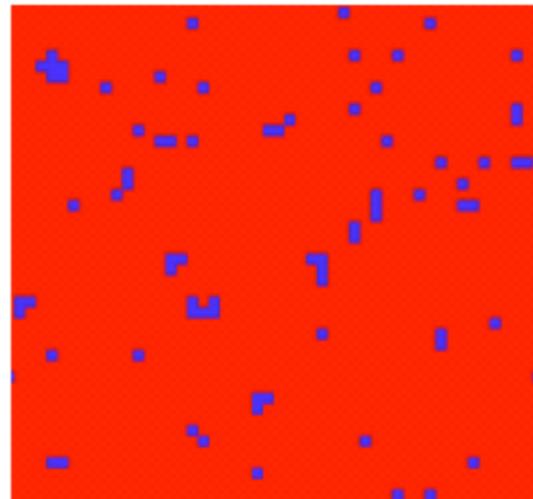
$T=3 \quad J/k_B$



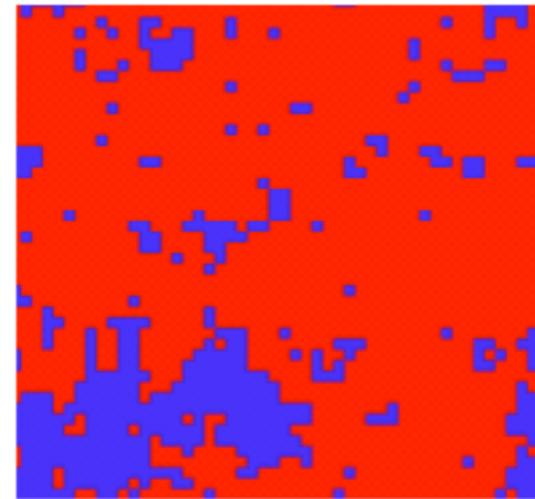
Modello di Ising



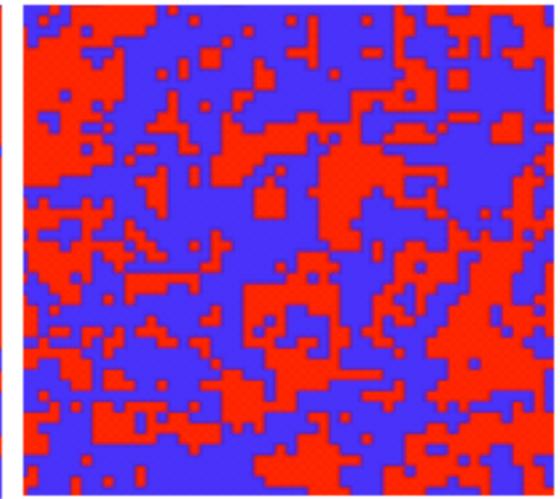
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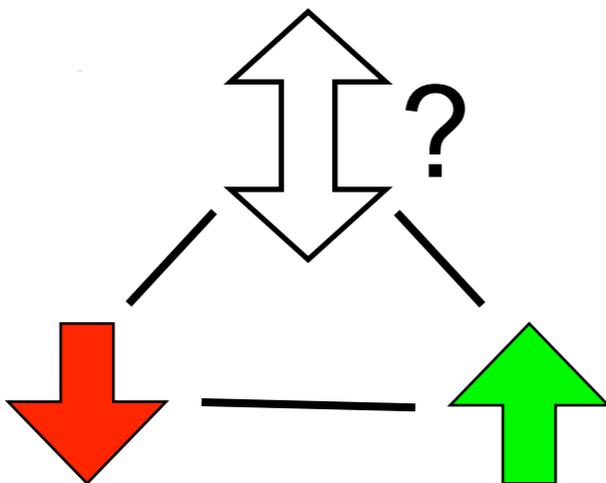
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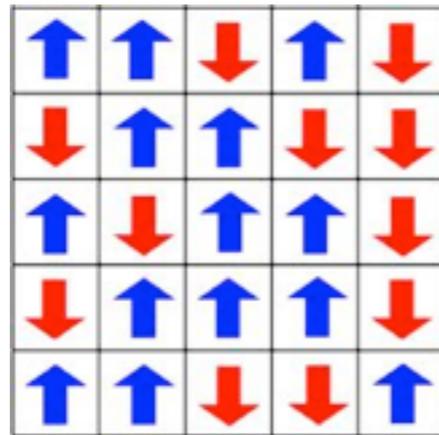
$T=3 \quad J/k_B$



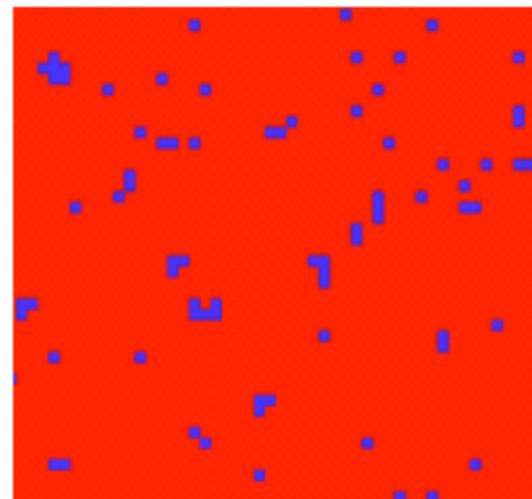
Spin glass



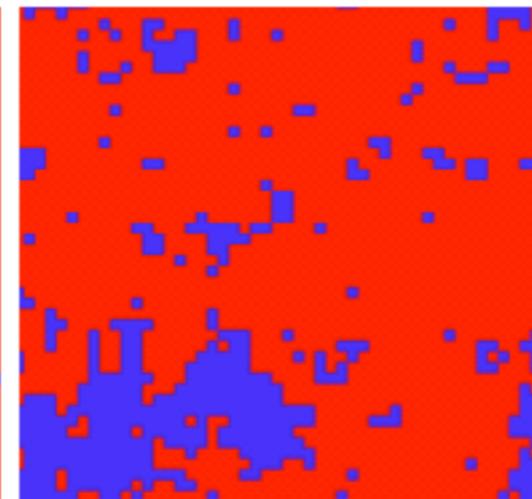
Modello di Ising



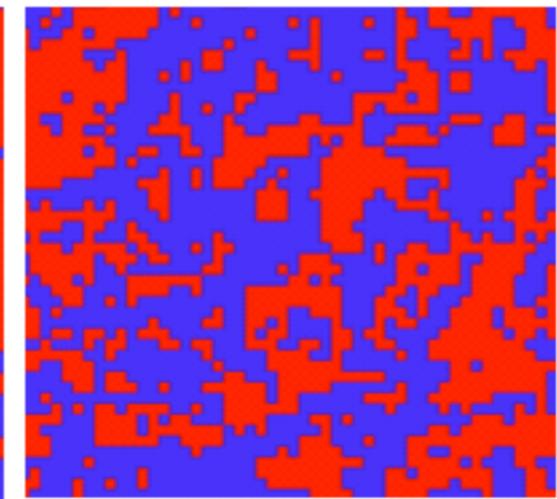
$T=2 \quad J/k_B$



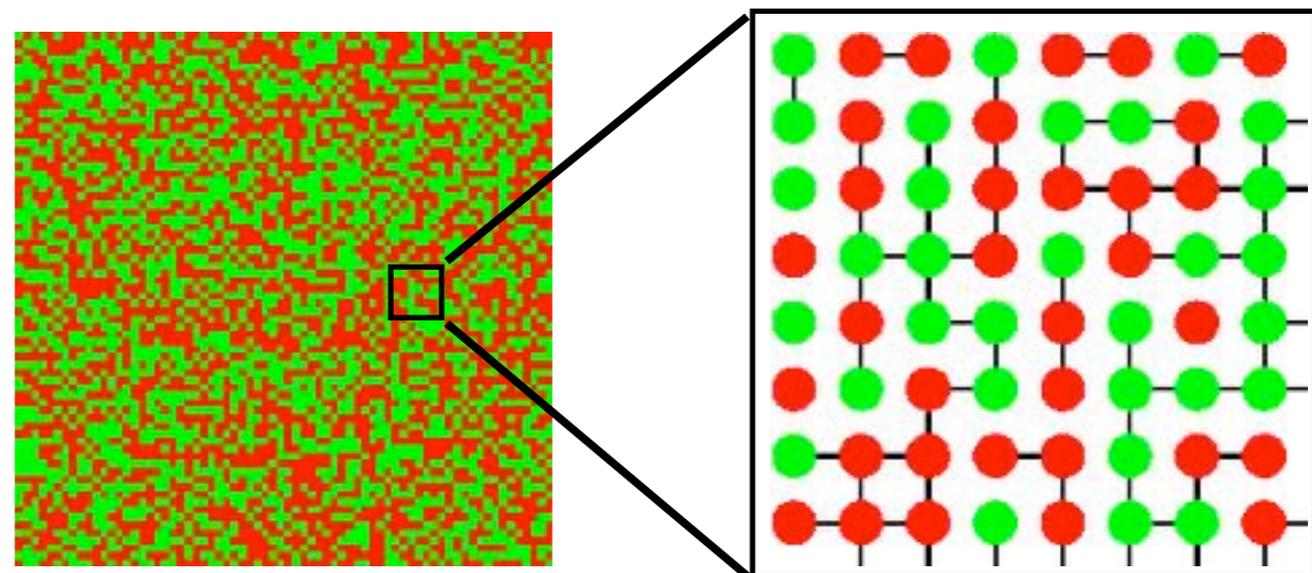
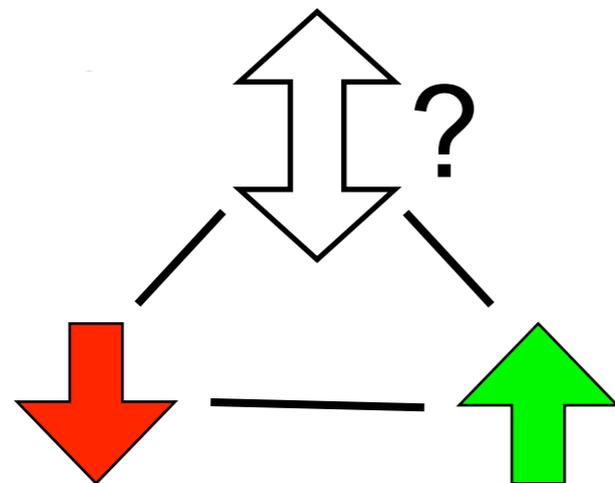
$T=T_c$



$T=3 \quad J/k_B$



Spin glass



Capire / risolvere un sistema complesso

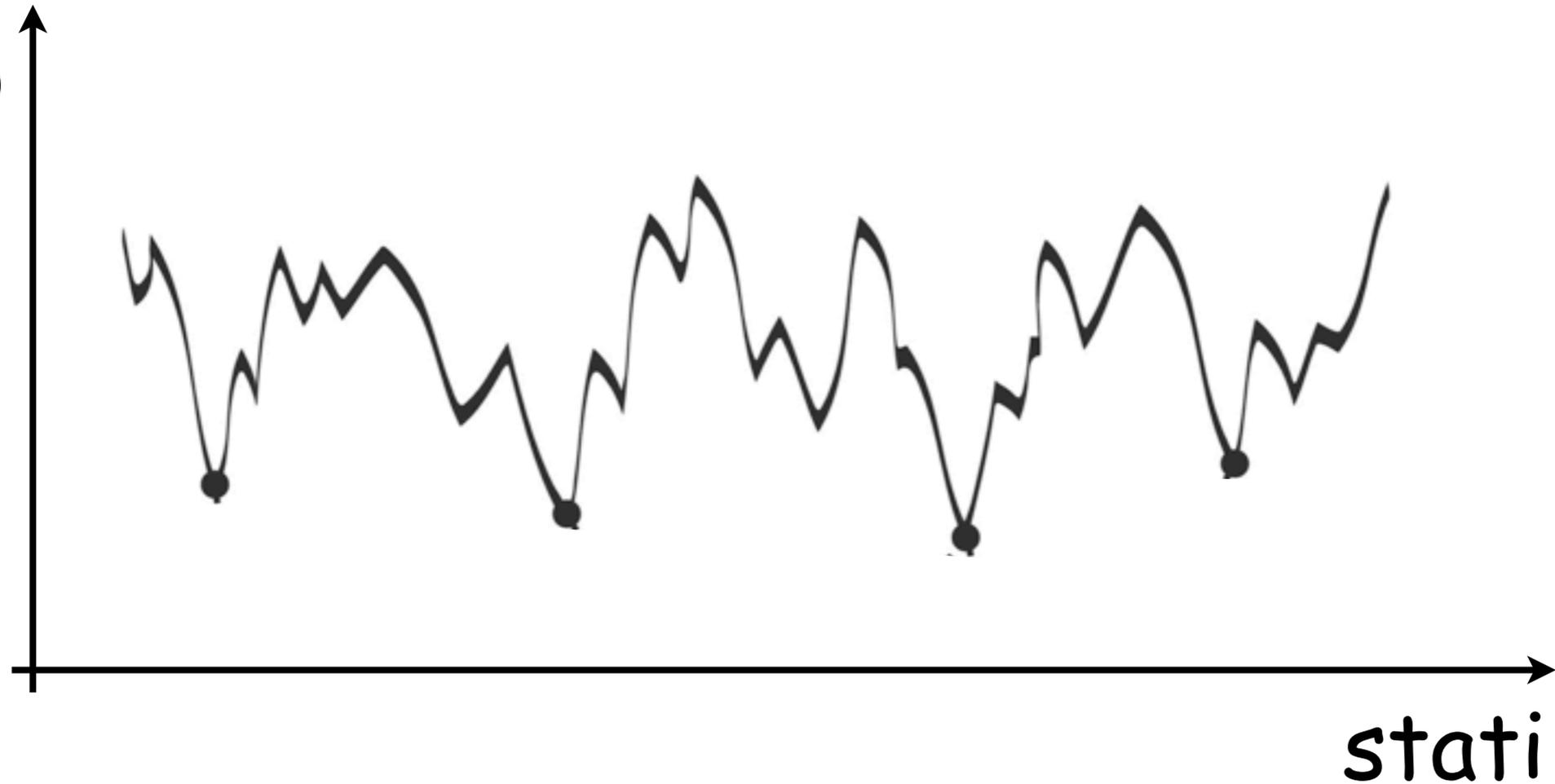
- Grande intuizione teorica
- Simulazione numerica di un modello complesso
 - ▶ esperimento virtuale
 - ▶ strumento \leftrightarrow algoritmo

Fisica computazionale

- *Importanza crescente*
- *Crescita esponenziale capacità di calcolo*
- *Scoperta di nuovi algoritmi !!*

Come visitare gli stati di un sistema complesso

energia
costo



Quanto hardware abbiamo?

Cervello umano:

10^{14} sinapsi \times 100 Hz = 10^7 GFLOPS

-> circa 10 Meuro

Cervello topo -> circa 10 keuro

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Cervello umano:

10^{14} sinapsi \times 100 Hz = 10^7 GFLOPS

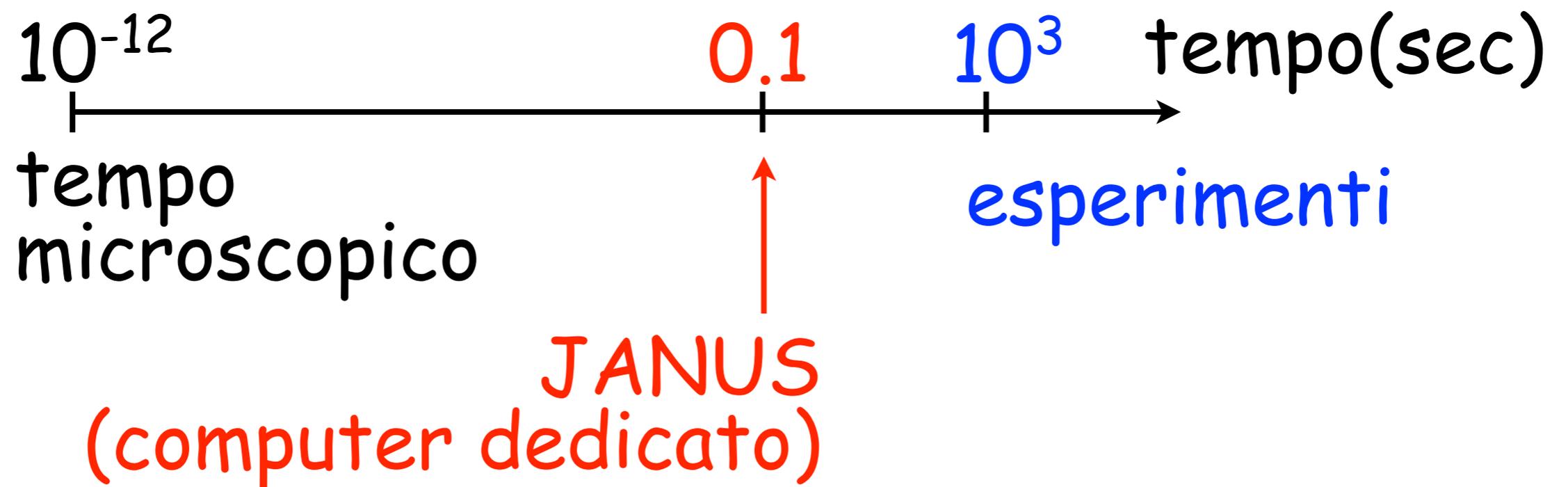
-> circa 10 Meuro

Cervello topo -> circa 10 keuro

...ma ci manca l'algoritmo!!

Quanto hardware abbiamo?

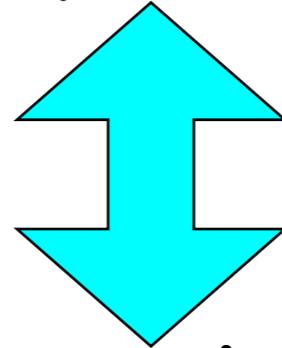
Simulazioni di spin glass



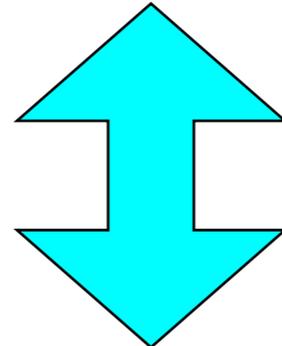
Cosa limita gli algoritmi?

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complessità



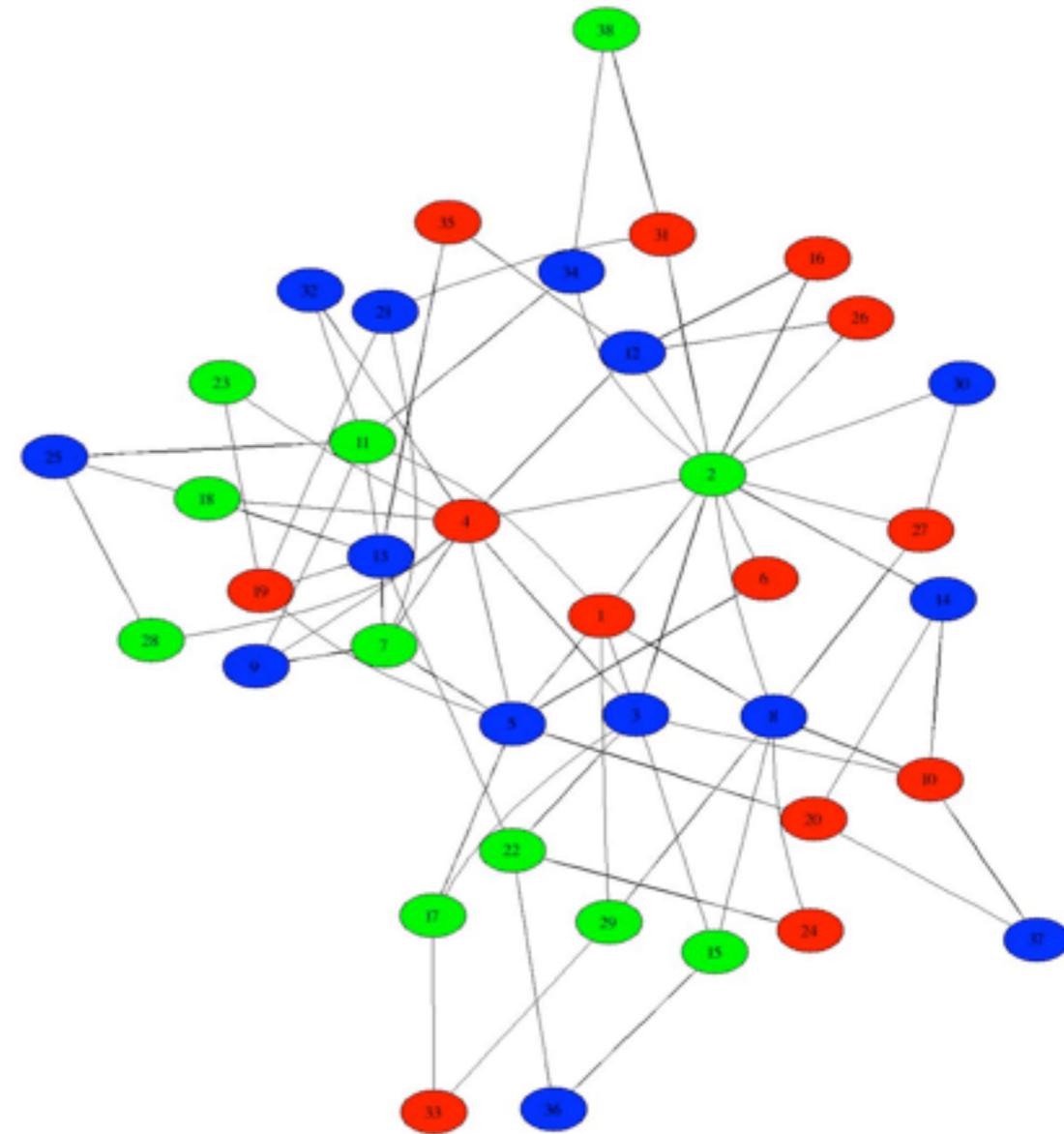
correlazioni a lungo raggio



transizioni di fase

Problemi di soddisfacimento di vincoli di vincoli

- Colorazione di un grafo



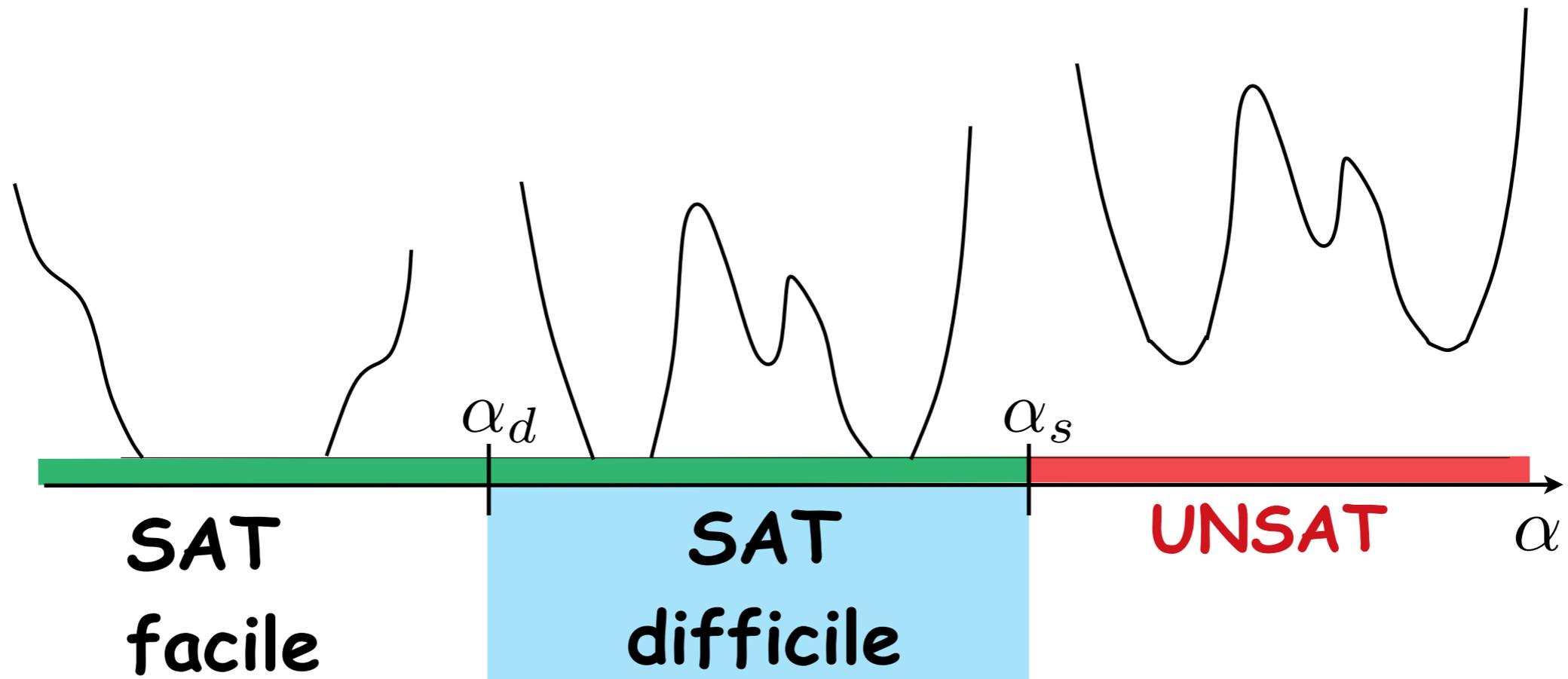
- Problemi SAT
(primo problema NP-complete, Cook 1971)

Random SAT problems



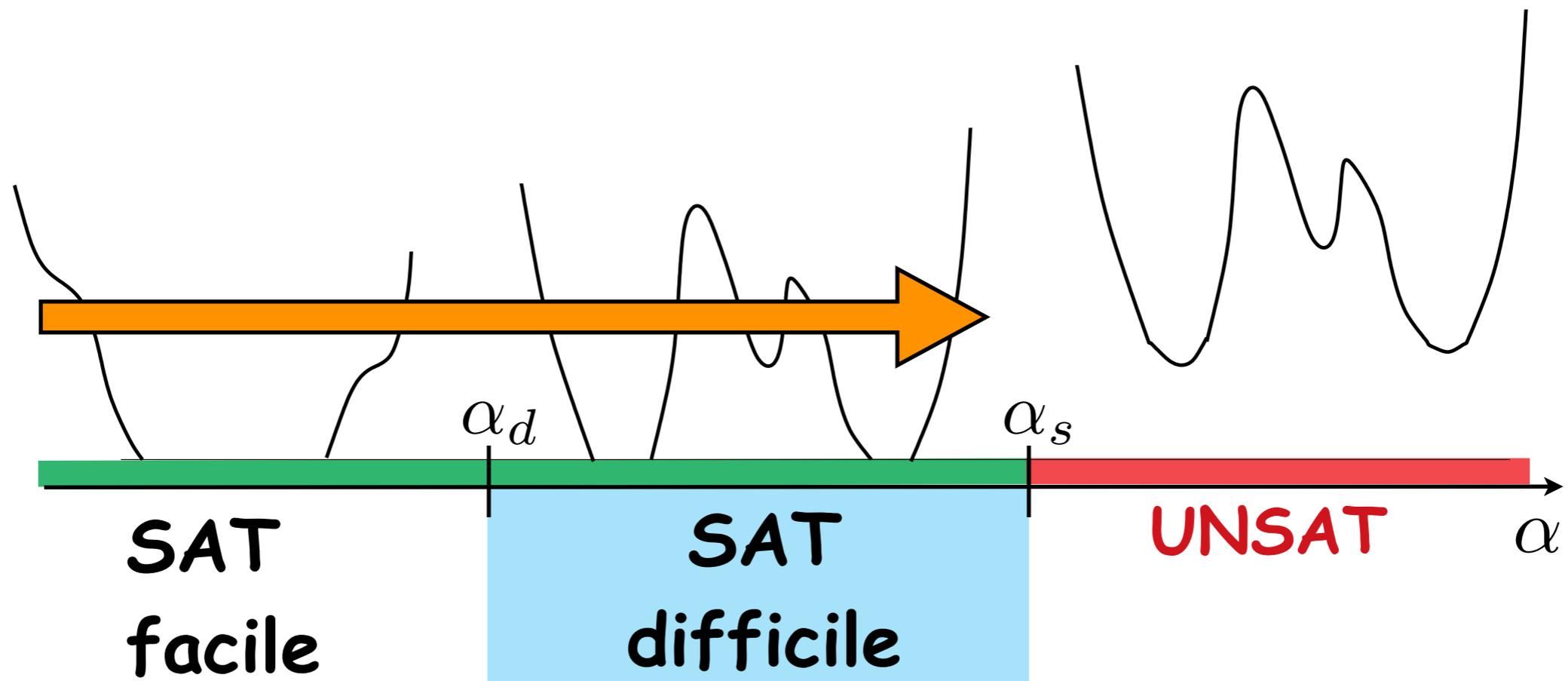
α = vincoli per variabile

Random SAT problems



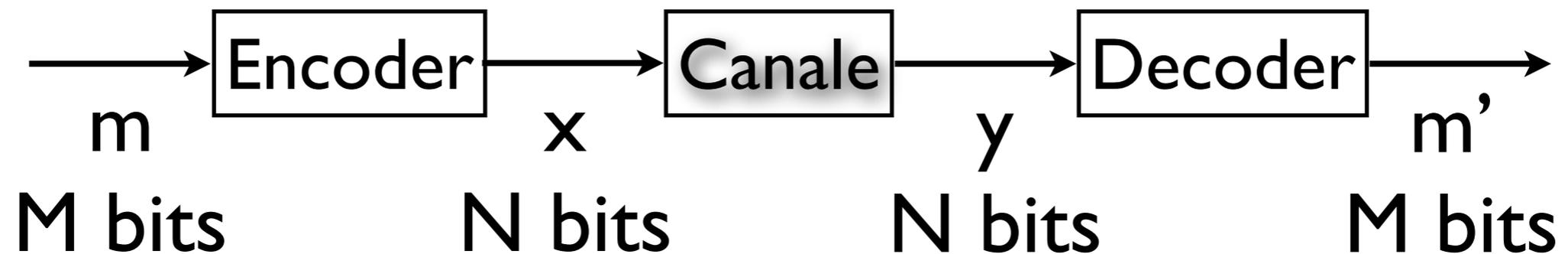
α = vincoli per variabile

Random SAT problems



α = vincoli per variabile

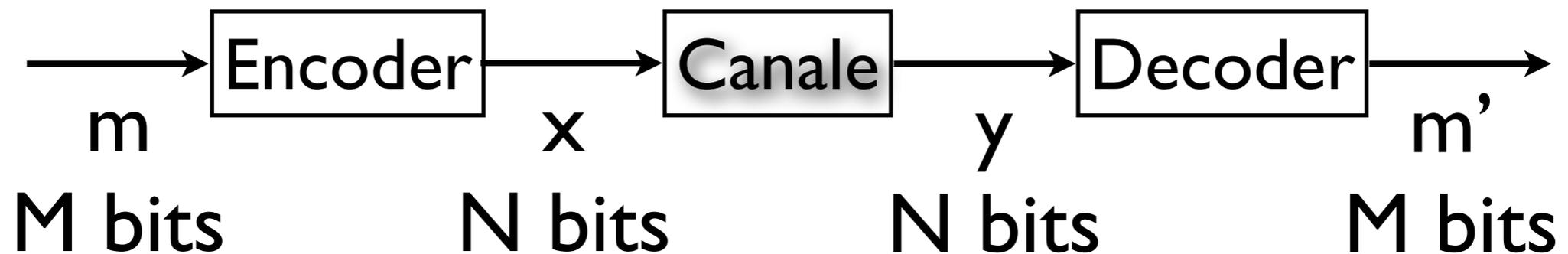
Codici correzione errori



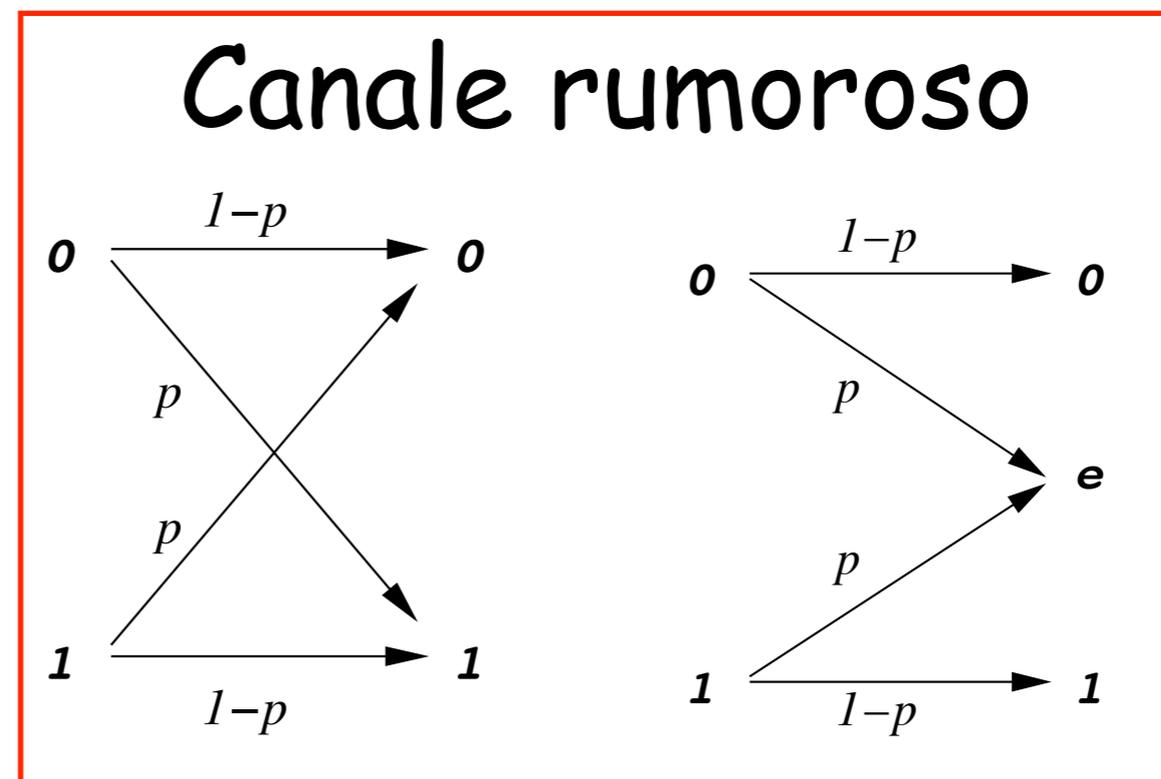
$$M < N$$

rate $R=M/N$

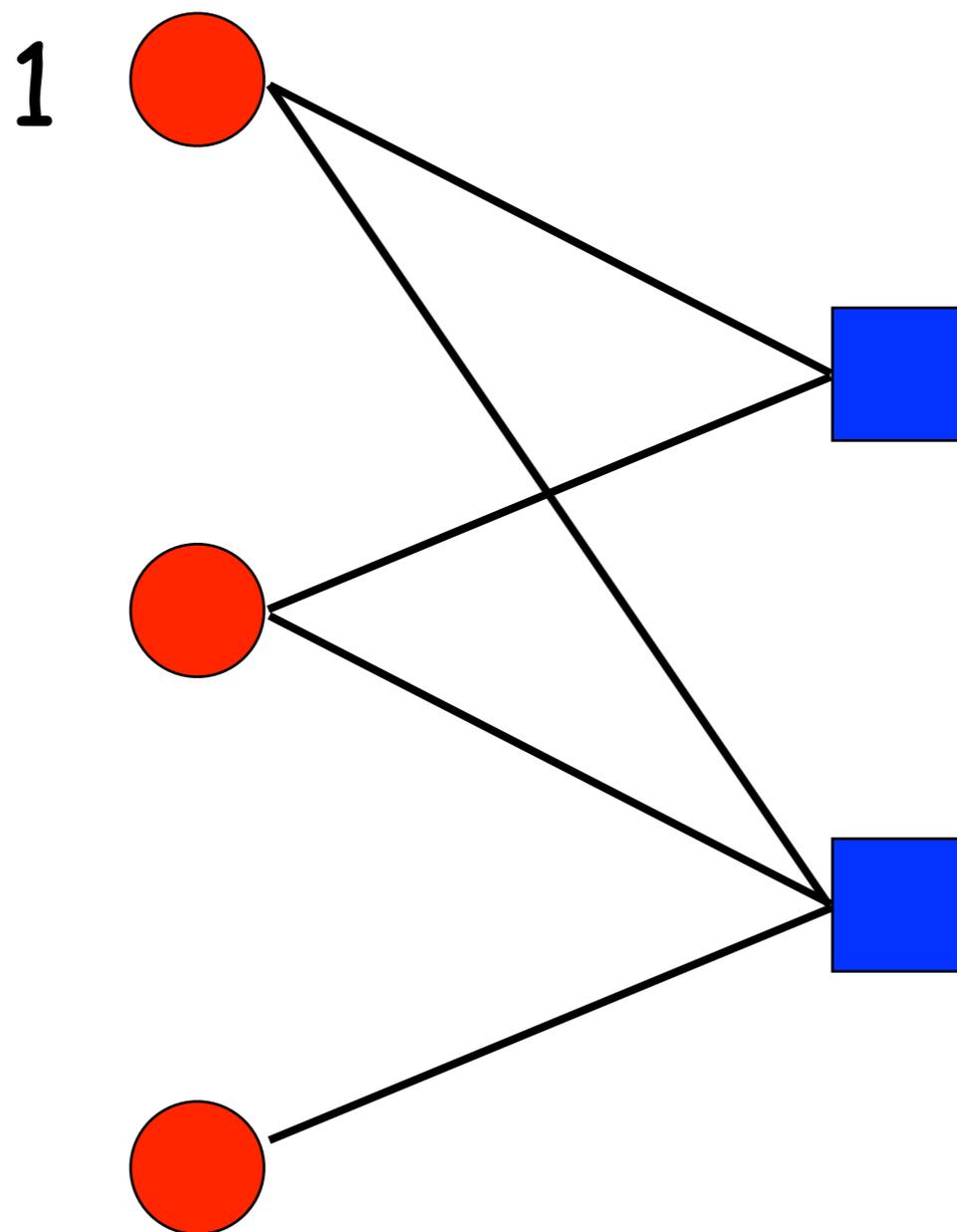
Codici correzione errori



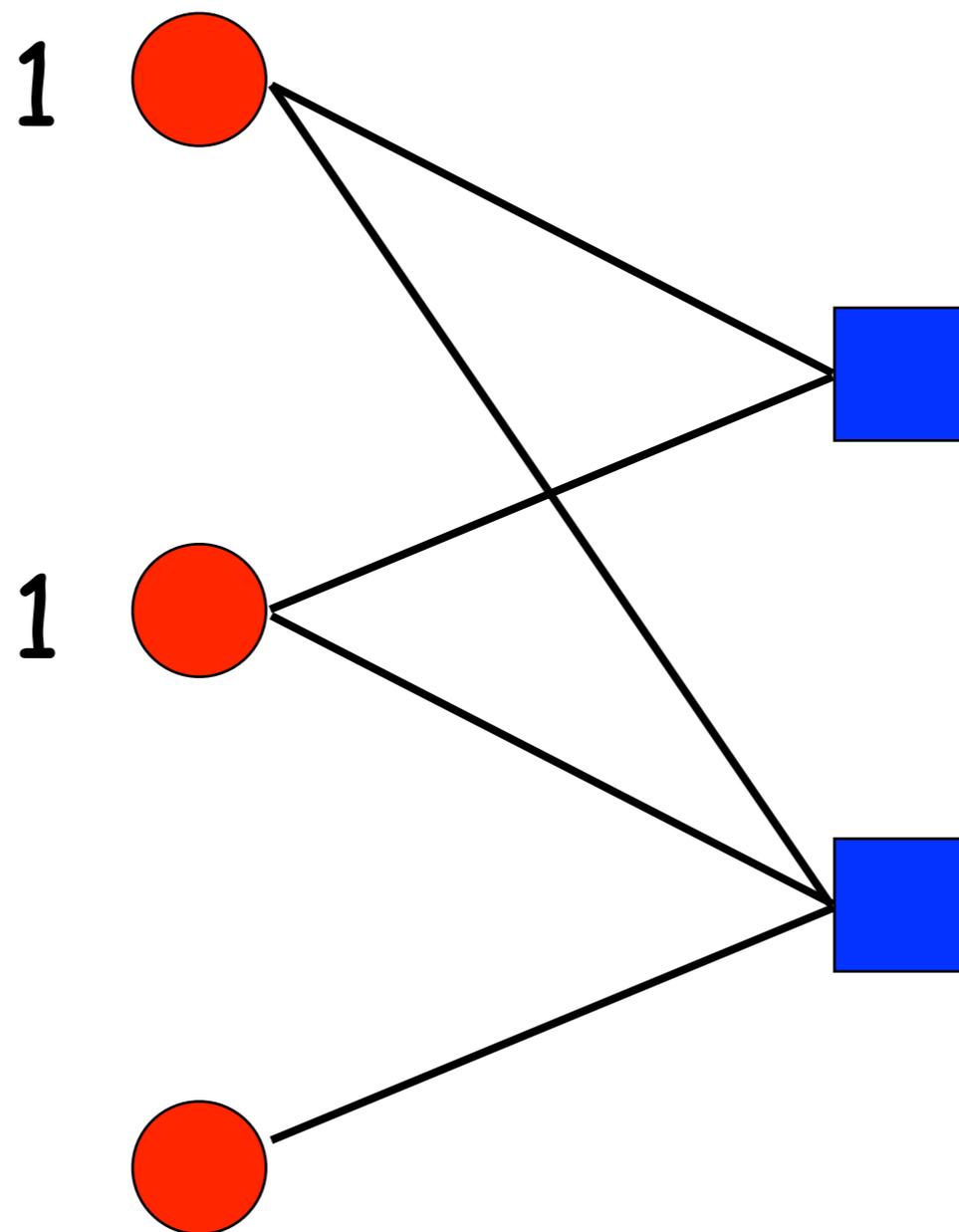
$M < N$
rate $R=M/N$



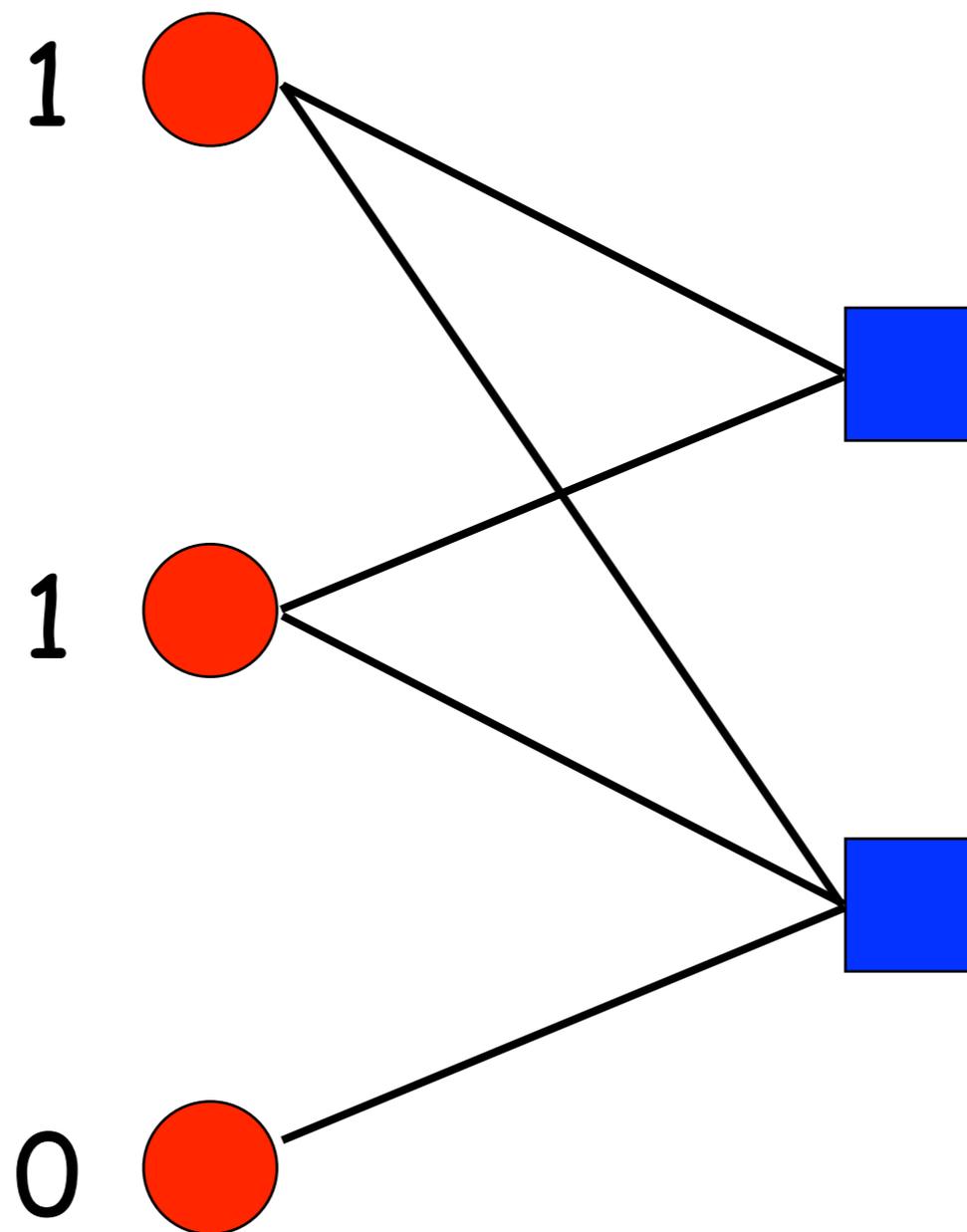
LDPC codes



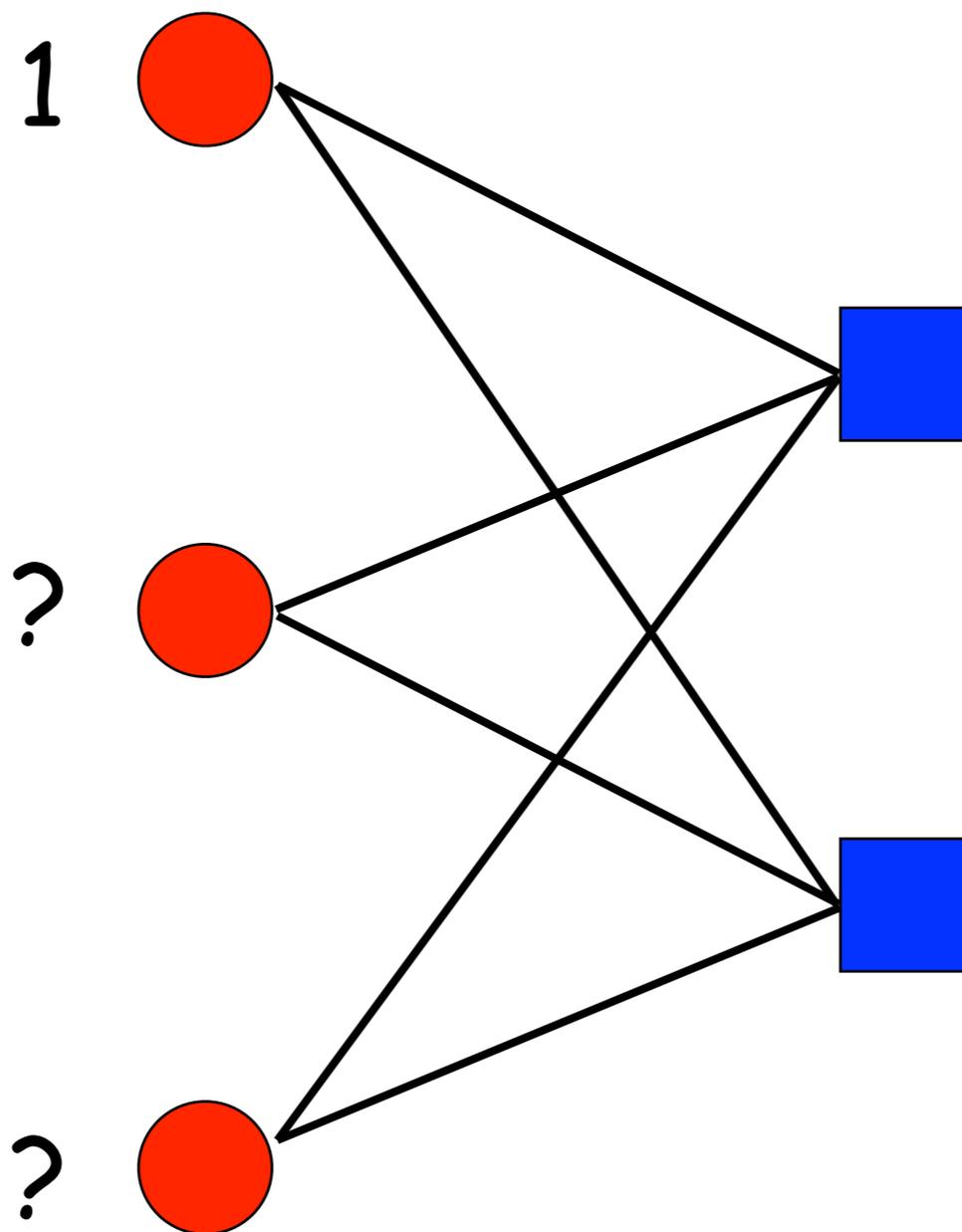
LDPC codes



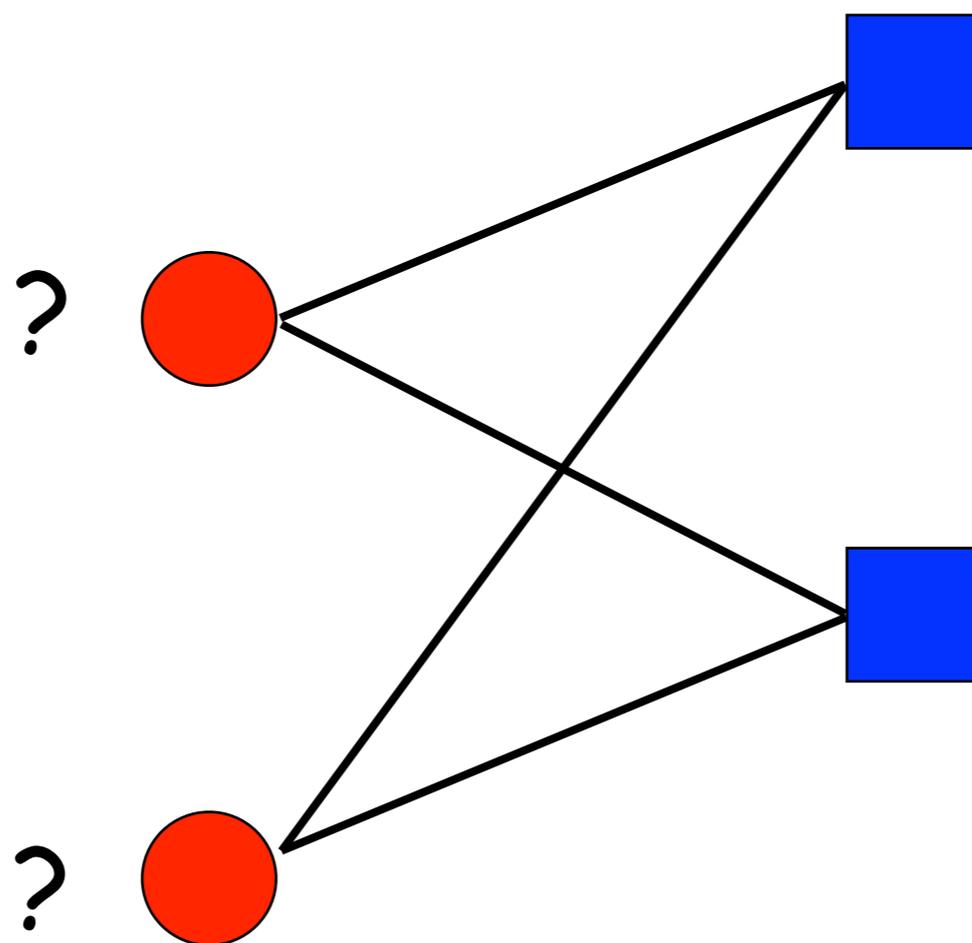
LDPC codes



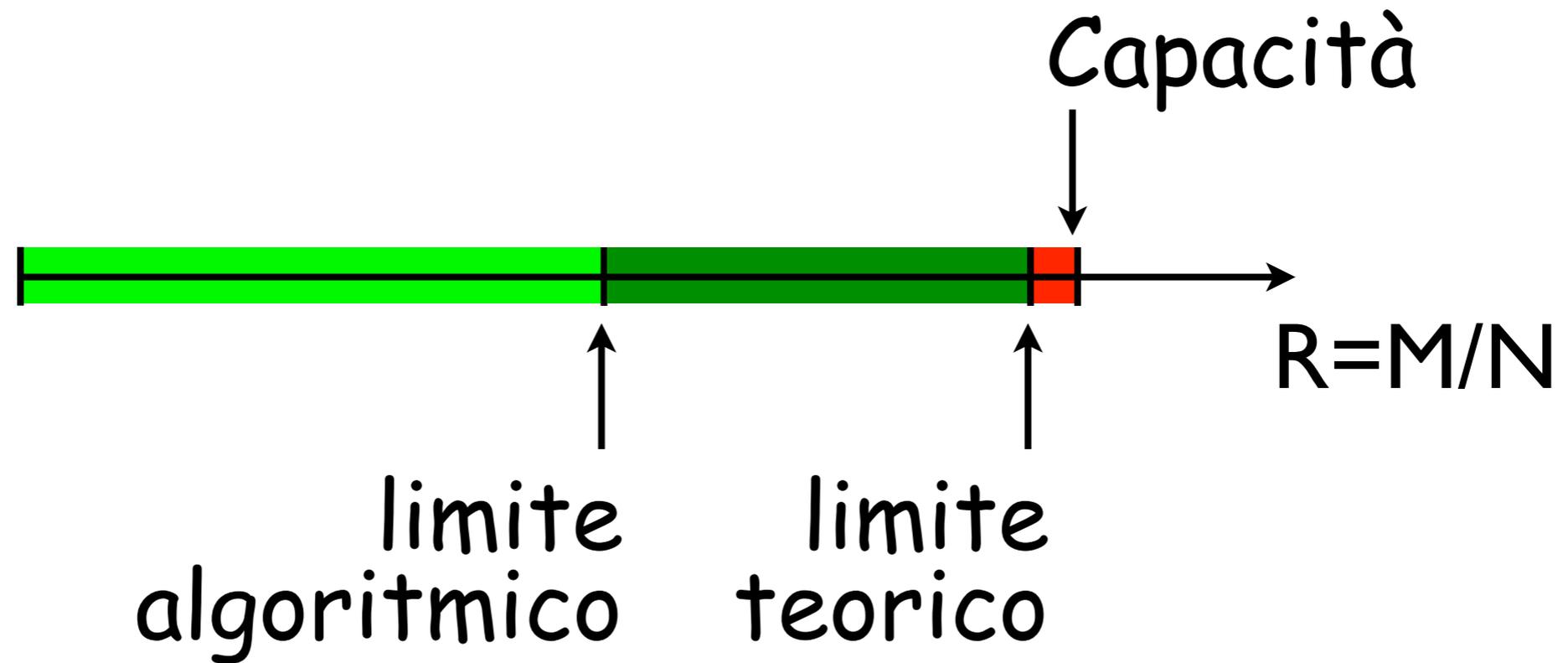
LDPC codes



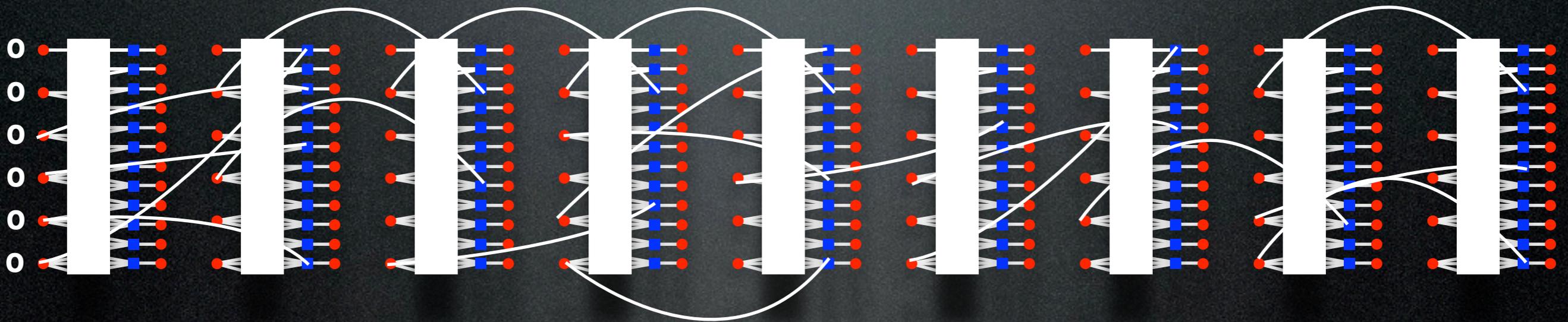
LDPC codes



LDPC codes



LDPC codes (spatial coupling)



limite algoritmico = limite teorico