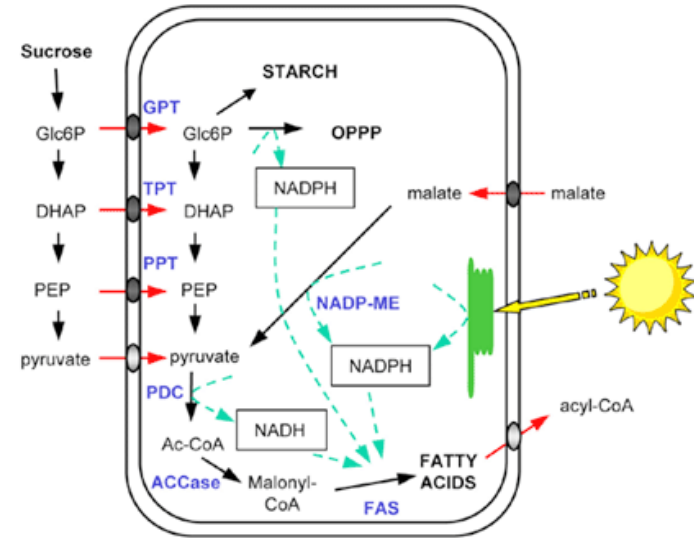




INSTITUTO DE FÍSICA
Universidade Federal Fluminense

Sistemas Complexos

Marcio Argollo de Menezes
IF-UFF

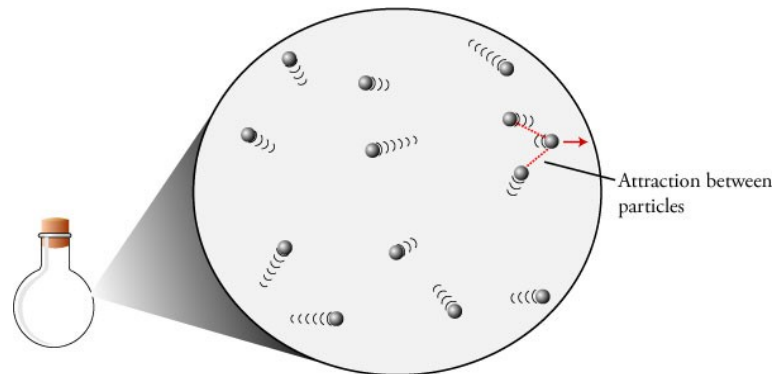


Abordagem sistêmica em Física

- Abstração de detalhes irrelevantes
 - Relação funcional entre elementos abstratos
 - Leis fundamentais
- Órbita de planetas, pressão de gases, etc

Gás ideal

(D. Bernoulli, 1738)



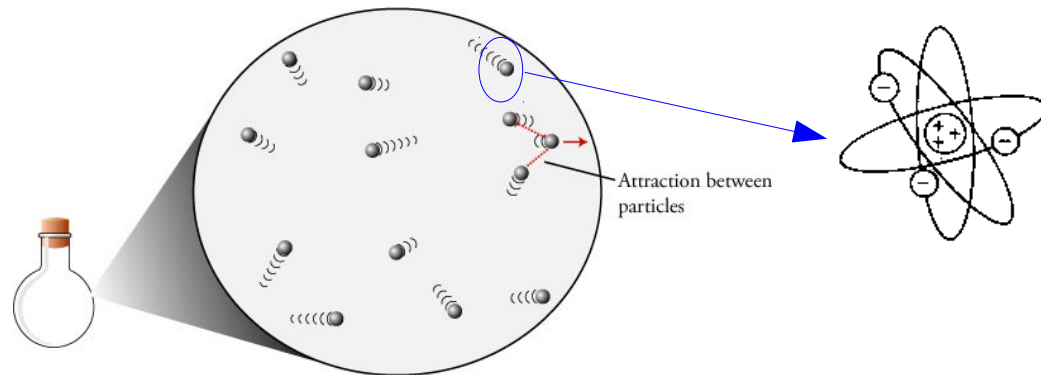
Abordagem sistêmica em Física

- Abstração de detalhes irrelevantes
 - Relação funcional entre elementos abstratos
 - Leis fundamentais
- Órbita de planetas, pressão de gases, etc

Gás ideal
(D. Bernoulli, 1738)



Teoria atômica
(E. Rutherford, 1911)



Abordagem sistêmica em Física

- Abstração de detalhes irrelevantes
 - Relação funcional entre elementos abstratos
 - Leis fundamentais
- Órbita de planetas, pressão de gases, etc

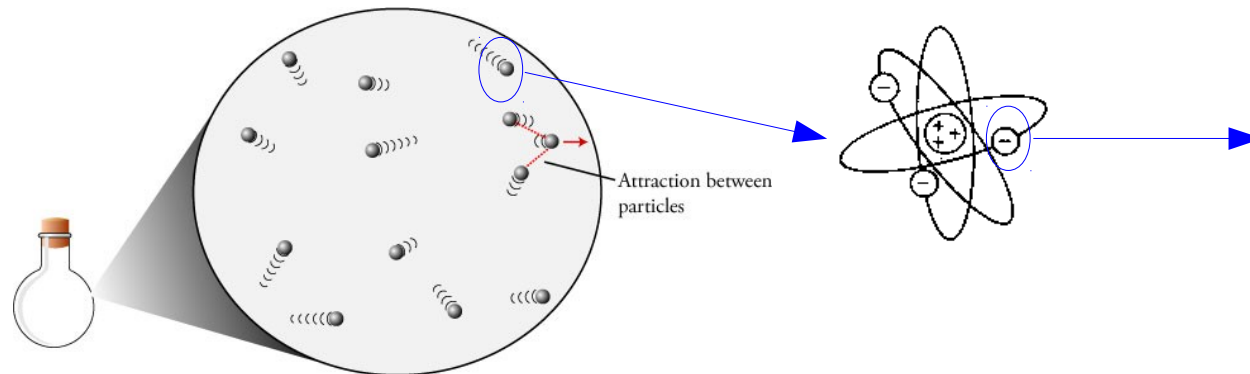
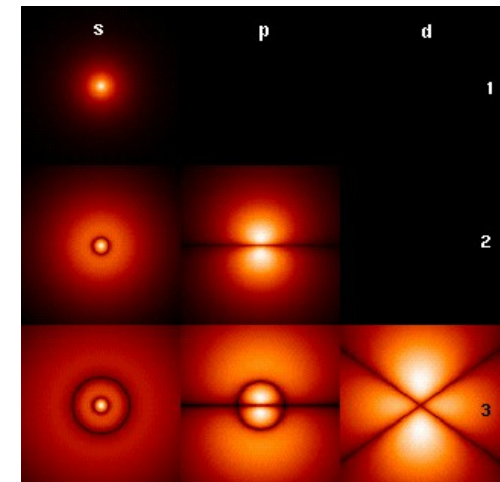
Gás ideal
(D. Bernoulli, 1738)



Teoria atômica
(E. Rutherford, 1911)



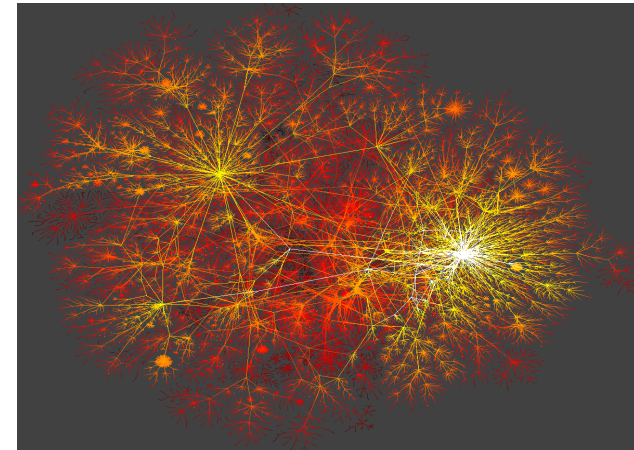
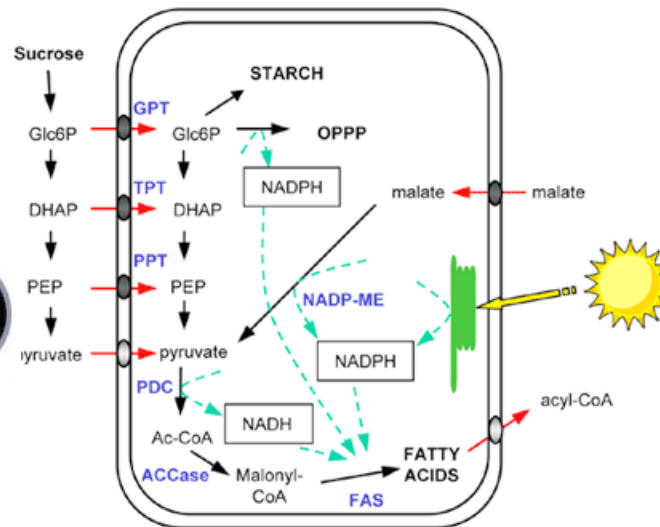
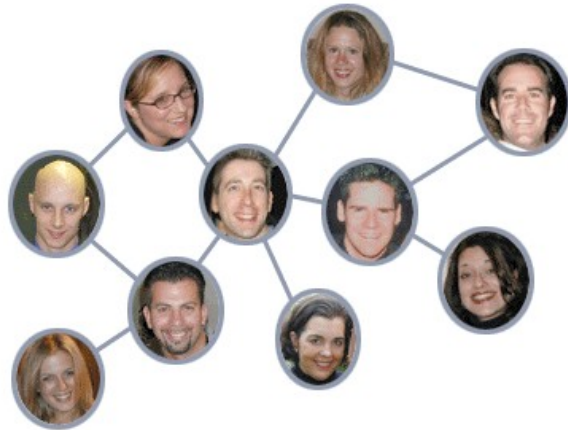
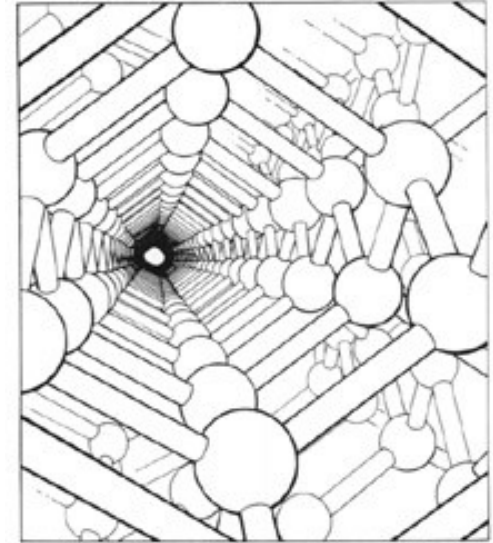
Teoria Quântica
(E. Schrödinger, 1926)



Redes: um paradigma de sistemas interagentes

Redes

- Físicas: estruturas cristalinas
- Relacionais: Sociais, econômicas
- Biológicas: Metabólicas, genéticas
- Tecnológicas: Internet, orkut

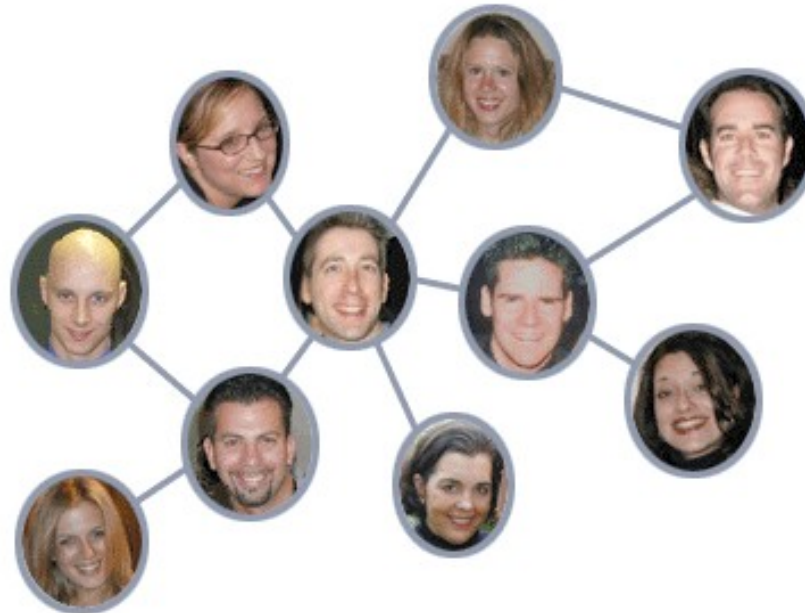


A experiência de Milgram

Stanley Milgram "The Small World Problem",
Psychology Today 2: 60-67 (1967).

http://en.wikipedia.org/wiki/Small_world_phenomenon

- Remetentes aleatoriamente escolhidos na costa leste dos EUA
- Destinatário na costa oeste
- Se remetente conhece o destinatário pessoalmente, entrega a carta
- Se não conhecer, entrega para amigo que possa conhecer o destinatário

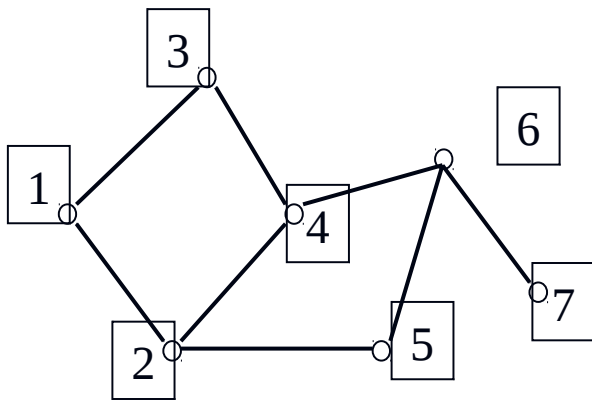


A experiência de Milgram

Stanley Milgram "The Small World Problem",
Psychology Today 2: 60-67 (1967).

http://en.wikipedia.org/wiki/Small_world_phenomenon

- Remetentes aleatoriamente escolhidos na costa leste dos EUA
- Destinatário na costa oeste
- Se remetente conhece o destinatário pessoalmente, entrega a carta
- Se não conhecer, entrega para amigo que possa conhecer o destinatário



$$l_{15}=2 \quad [1 \rightarrow 2 \rightarrow 5]$$

$$l_{17}=4 \quad [1 \rightarrow 3 \rightarrow 4 \rightarrow 6 \rightarrow 7]$$

...

$$\langle l \rangle = ??$$

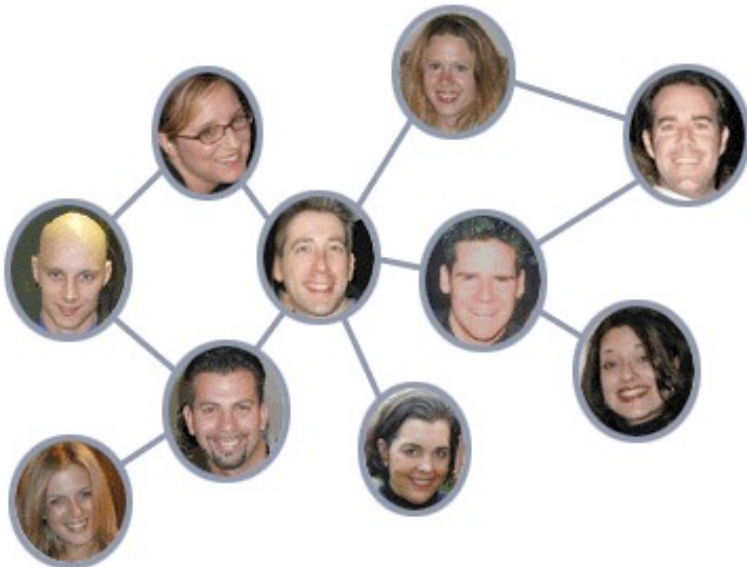


A experiência de Milgram

Stanley Milgram "The Small World Problem",
Psychology Today 2: 60-67 (1967).

http://en.wikipedia.org/wiki/Small_world_phenomenon

- Remetentes aleatoriamente escolhidos na costa leste dos EUA
- Destinatário na costa oeste
- Se remetente conhece o destinatário pessoalmente, entrega a carta
- Se não conhecer, entrega para amigo que possa conhecer o destinatário



“Seis graus de liberdade”

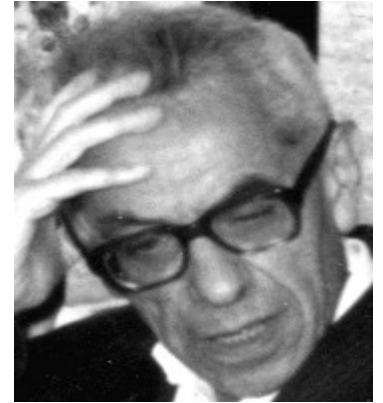
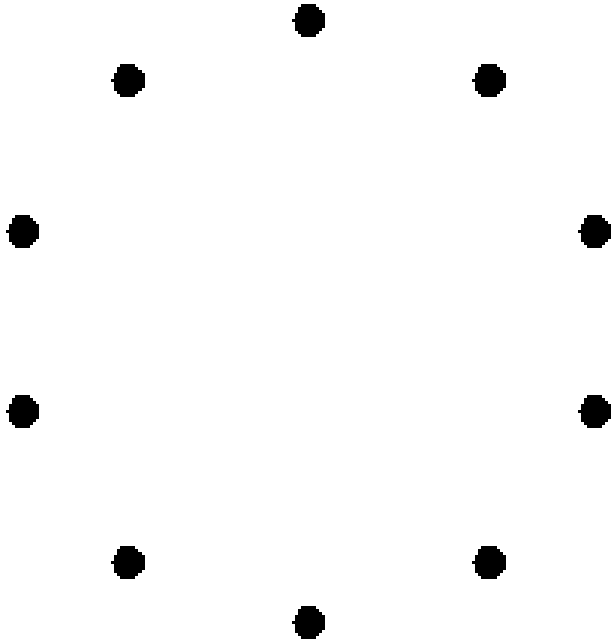
N ~ 10⁶ pessoas nos EUA

$\langle l \rangle \sim 6$ amigos

Grafos Aleatórios de Erdős-Rényi

P. Erdos and A. Renyi. On random graphs. Publ. Math. Debrecen, 6:290--297, 1959.

http://en.wikipedia.org/wiki/Paul_Erdos

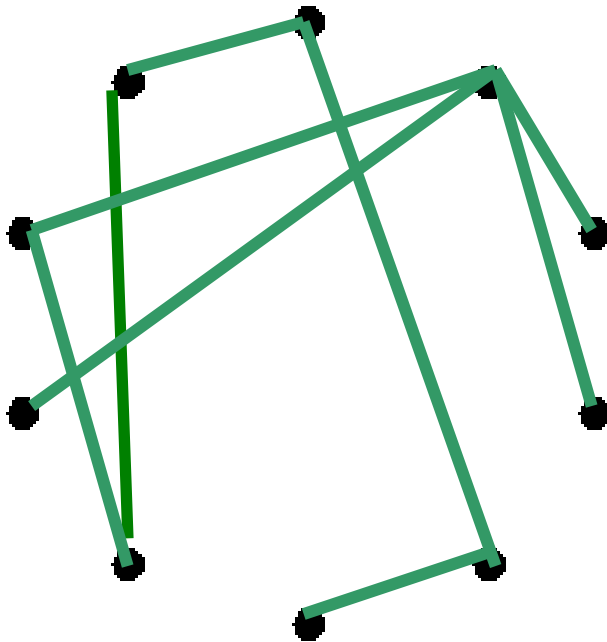


Pál Erdős
(1913-1996)

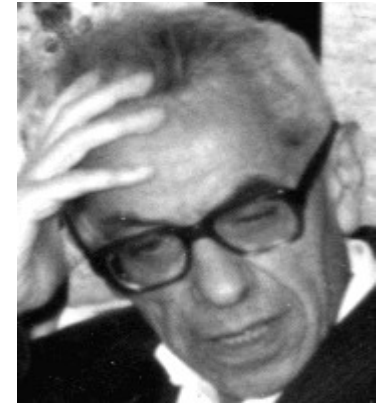
Grafos Aleatórios de Erdős-Rényi

P. Erdős and A. Rényi, "On random graphs",
Publ. Math. Debrecen, 6:290--297, 1959.

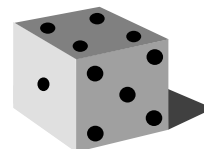
http://en.wikipedia.org/wiki/Paul_Erdos



**Pares de sítios
conectados c/
prob. p**



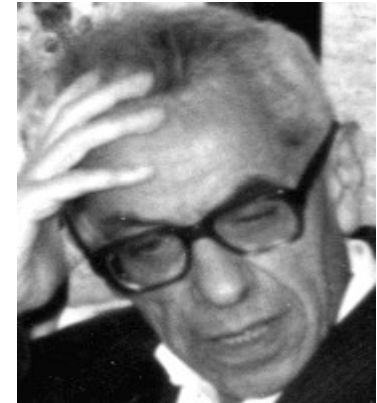
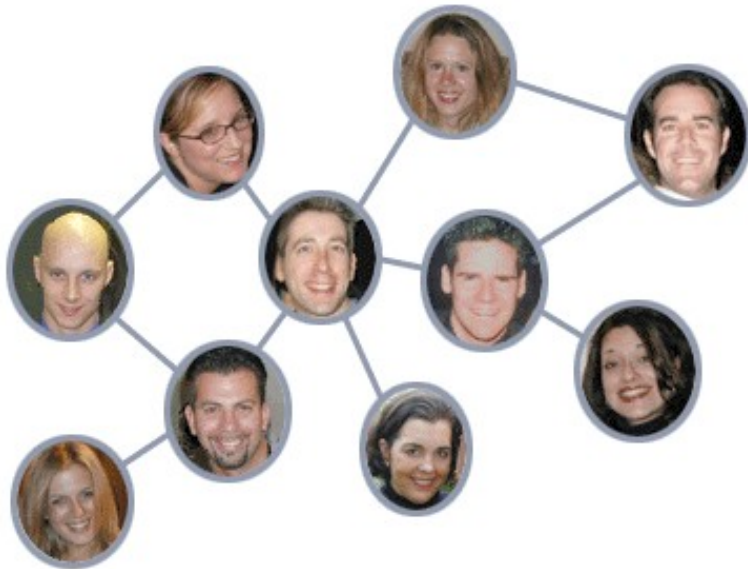
Pál Erdős
(1913-1996)



Grafos Aleatórios de Erdős-Rényi

P. Erdős and A. Rényi, "On random graphs",
Publ. Math. Debrecen, 6:290--297, 1959.

http://en.wikipedia.org/wiki/Paul_Erdos



Pál Erdős
(1913-1996)

“Seis graus de liberdade”

$N \sim 10^6$

$\langle l \rangle \sim 6$ amigos

Paul Erdős and his Mathematics

4th-11th of July, 1999. Budapest



Organized by:

Organizing committee:

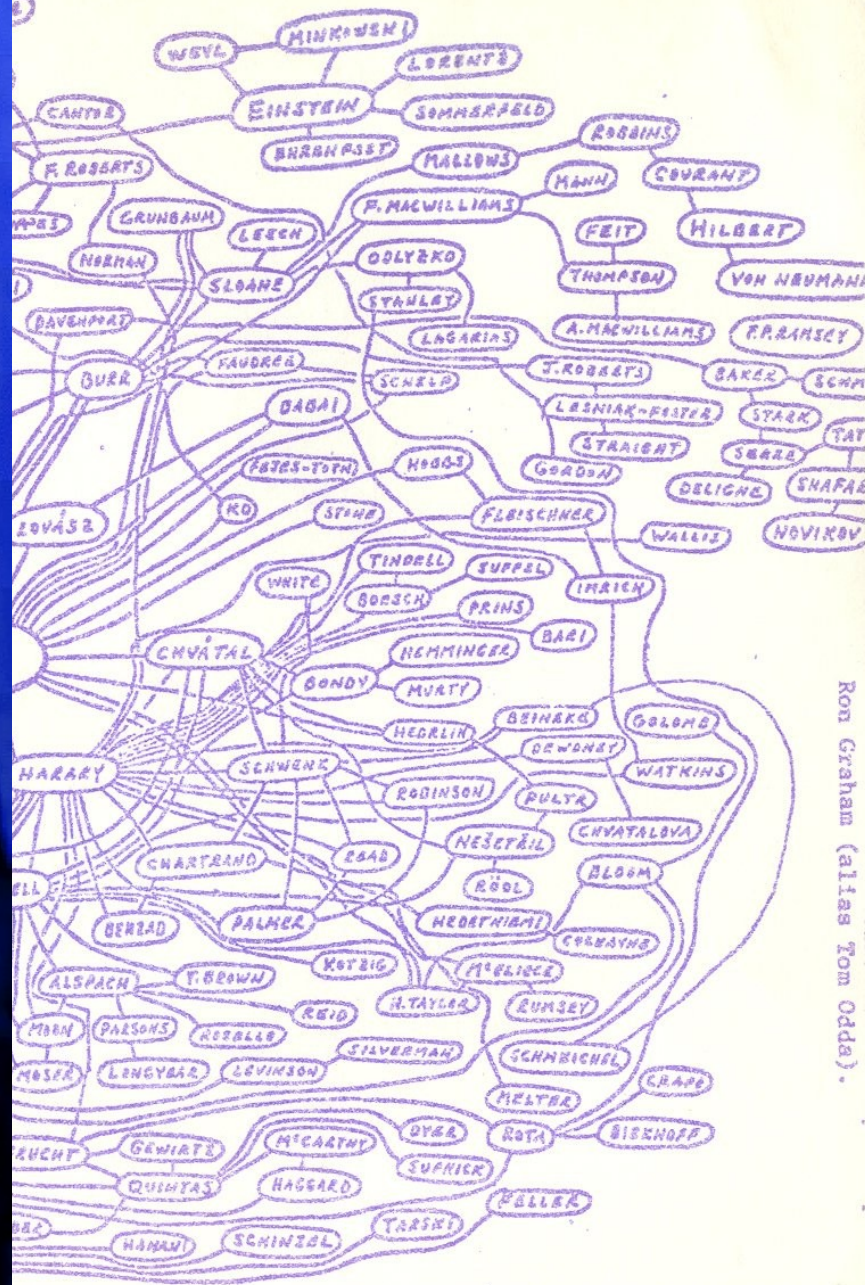
Honorary Speakers:

Sponsors:

Contact persons:

Postal Address:

URL: <http://www.math-inst.hu/~erdos99>



Ron Graham (alias Tom Odde).

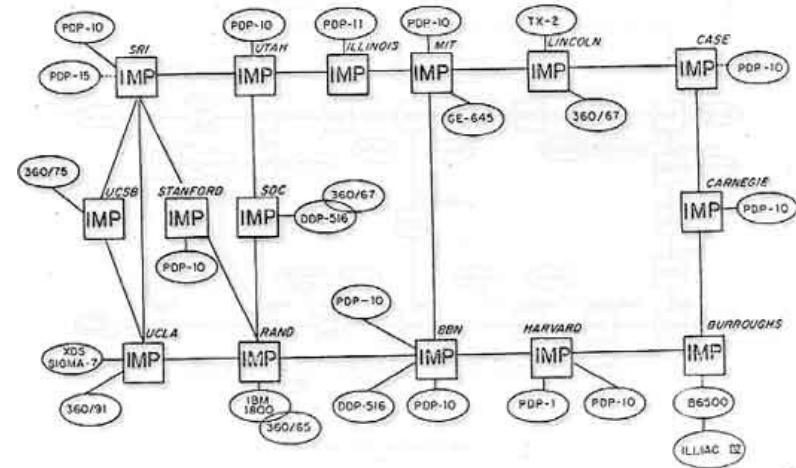
A Internet

- 1957 - União Soviética lança com sucesso o Sputnik
- 1962 - DoD cria sistema de informação resistente a desastres (nucleares)



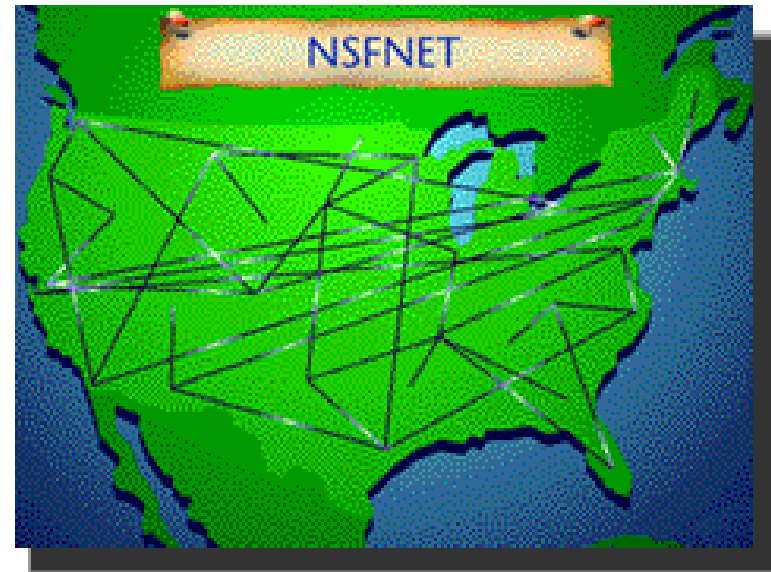
A Internet

- 1957 - União Soviética lança com sucesso o Sputnik
- 1962 - DoD cria sistema de informação resistente a desastres (nucleares)
- Militares transferem sistema para universidades (ARPANET)



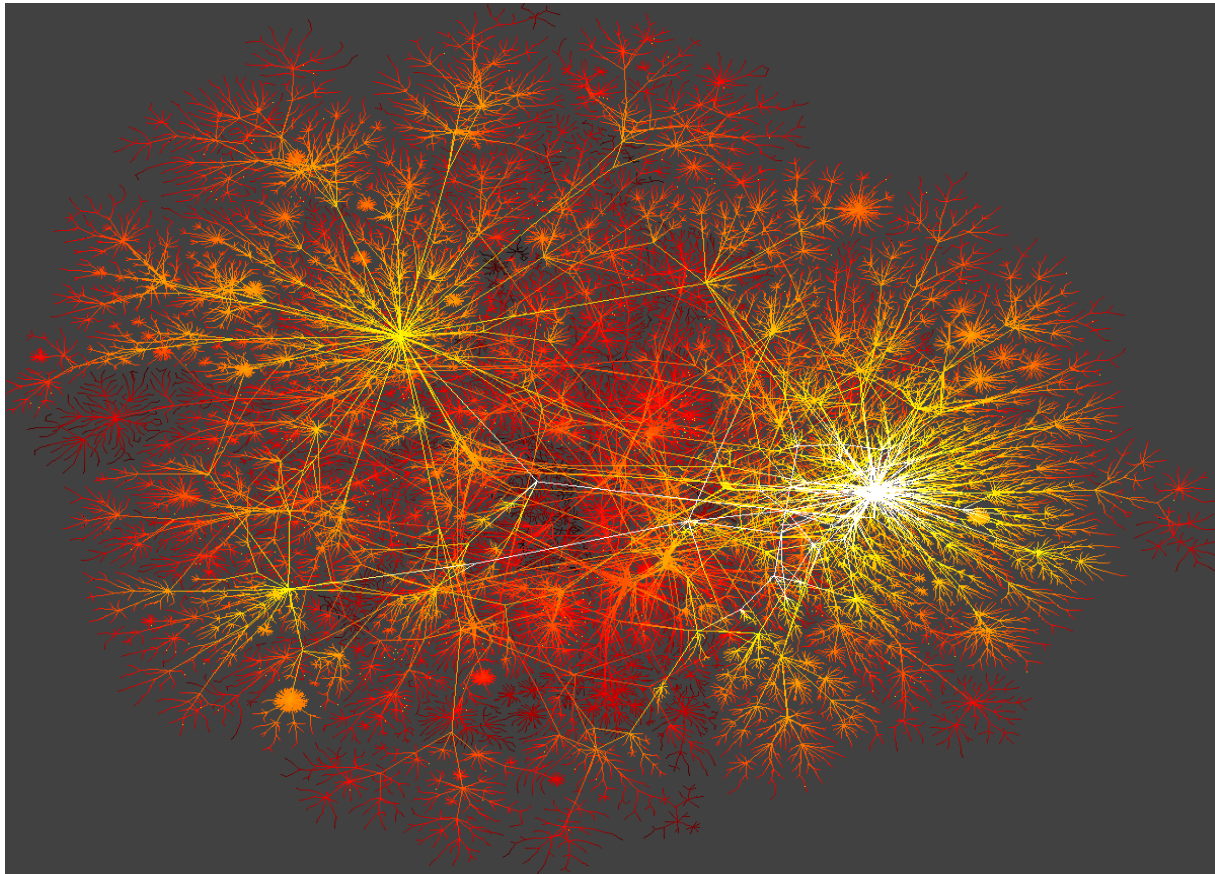
A Internet

- 1957 - União Soviética lança com sucesso o Sputnik
- 1962 - DoD cria sistema de informação resistente a desastres (nucleares)
- Militares transferem sistemas para universidades (ARPANET)
- NSFNET - Backbone + sub-redes (MCI, Sprint)



A Internet

- 1957 - União Soviética lança com sucesso o Sputnik
- 1962 - DoD cria sistema de informação resistente a desastres (nucleares)
- Militares transferem sistemas para universidades (ARPANET)
- NSFNET - Backbone + sub-redes (MCI, Sprint)
- Aumento exponencial no número de sub-redes

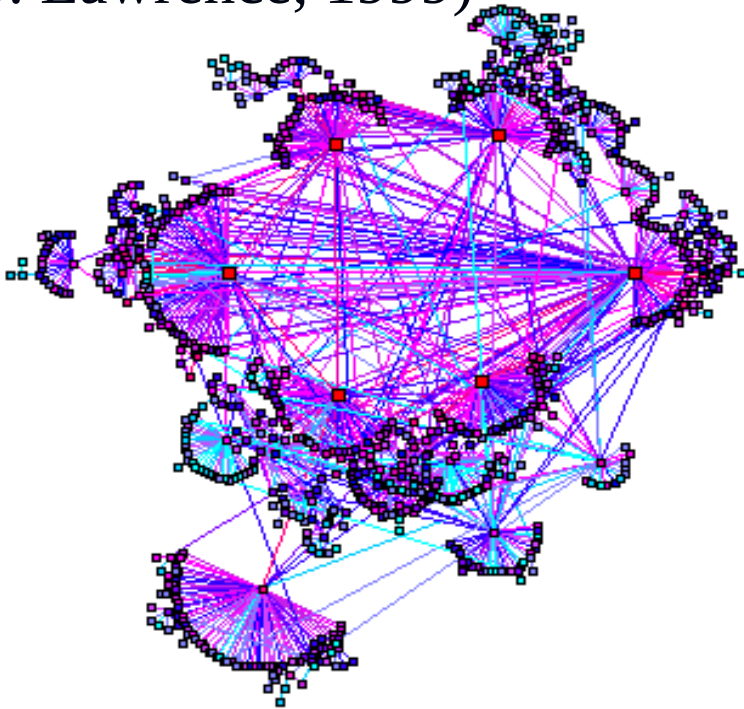


World Wide Web

Sítios: Páginas de hipertexto

Ligações: Links de hipertexto

800 milhões de páginas
(S. Lawrence, 1999)



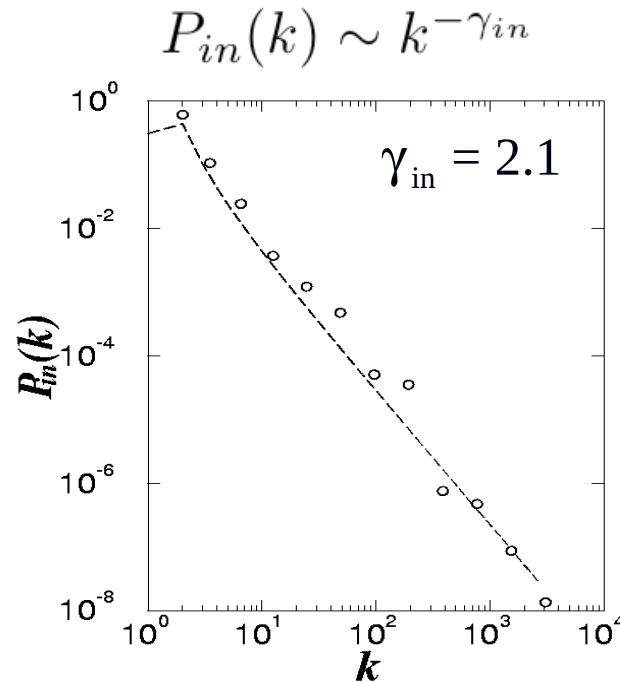
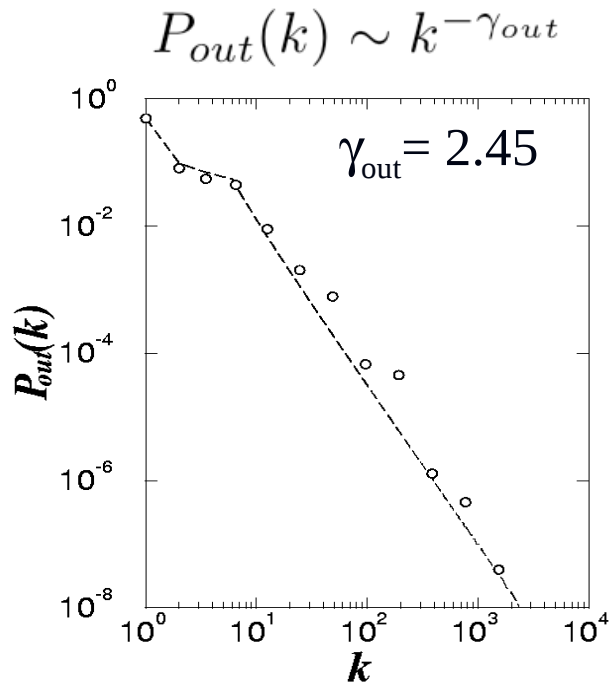
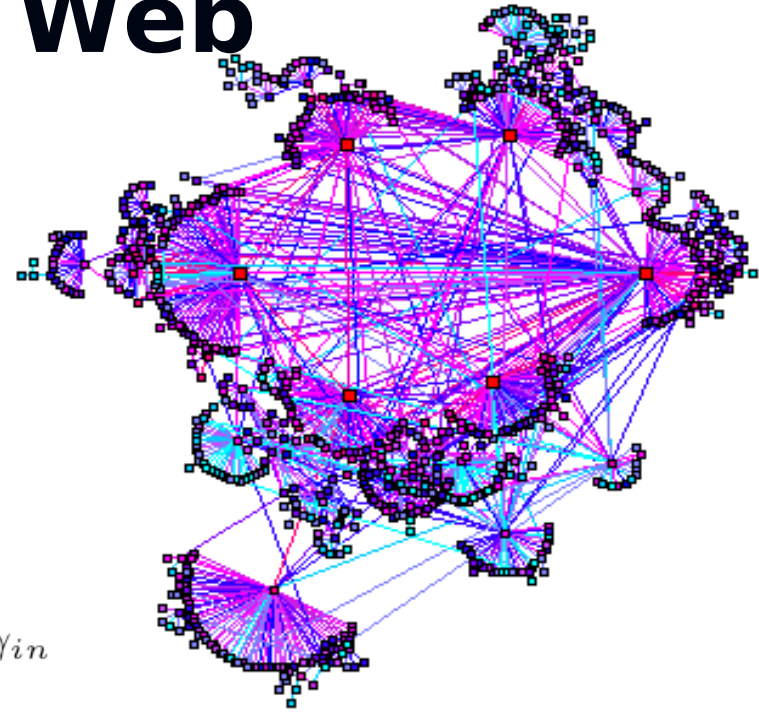
ROBOT: colecciona todos os links de uma dada página e segue buscando por outras recursivamente.

World Wide Web

Sítios: Páginas de hipertexto

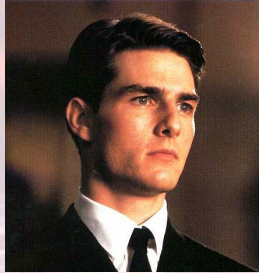
Ligações: Links de hipertexto

800 milhões de páginas
(S. Lawrence, 1999)



ACTOR CONNECTIVITIES

oracleofbacon.org



Days of Thunder
(1990) Far and Away
(1992) Eyes Wide
Shut (1999)

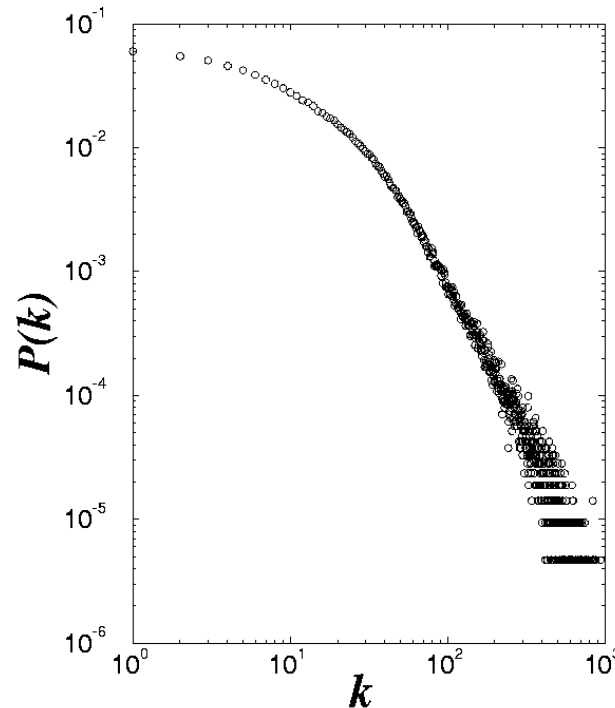


$N = 212,250$ atores

$\langle k \rangle = 28.78$

$P(k) \sim k^{-\gamma}$

$\gamma = 2.3$

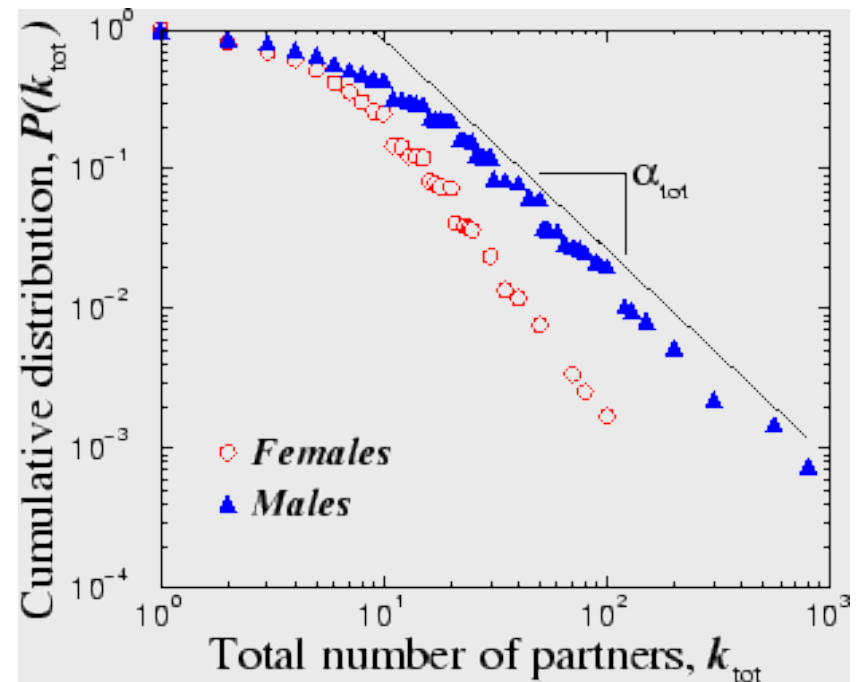




Sex-web

Nodes: people (Females; Males)

Links: sexual relationships



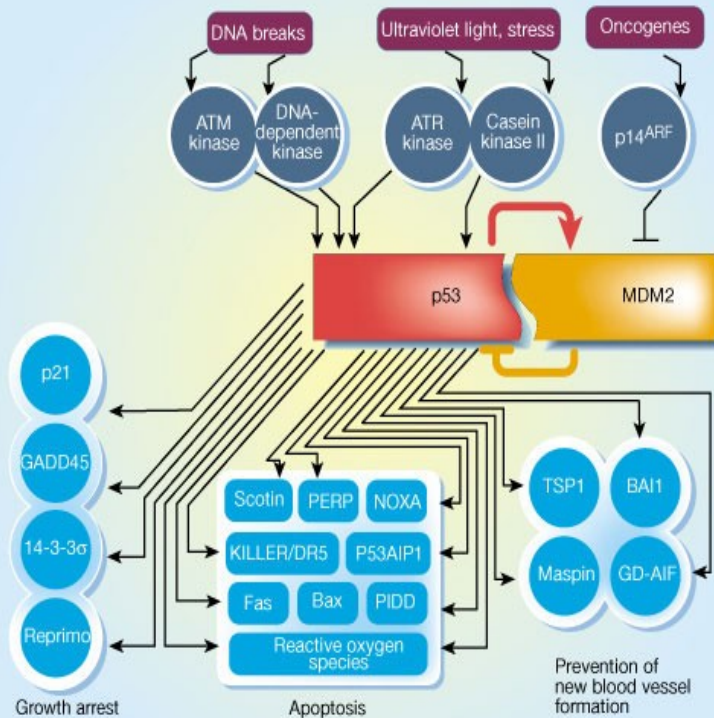
“The Web of Human Sexual Contacts”

F.Liljeros et al. Nature (2001) **411**:
908 4781 Suecos entre 18-74 anos

Surfing the p53 network

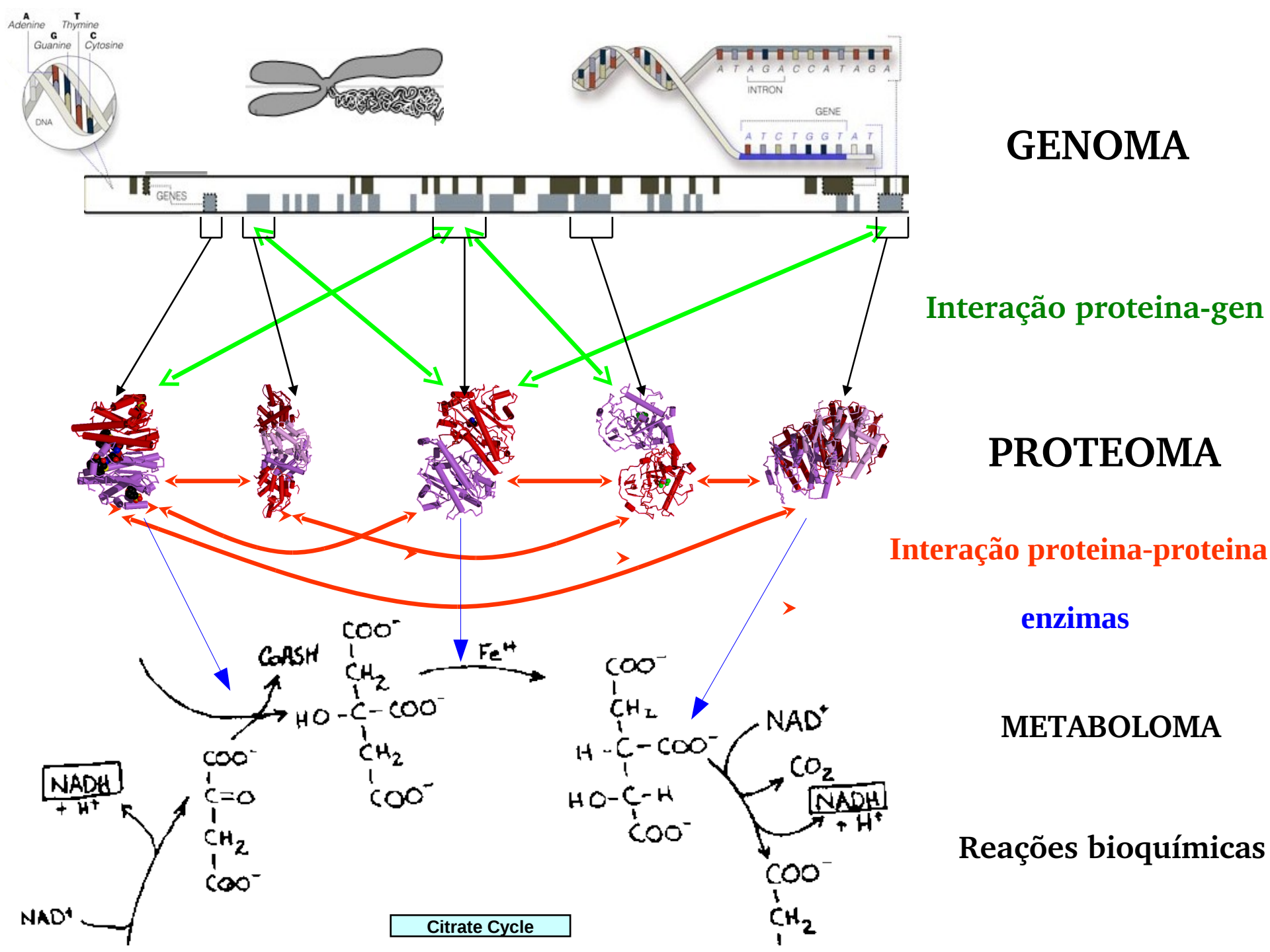
Bert Vogelstein, David Lane and Arnold J. Levine

The p53 tumour-suppressor gene integrates numerous signals that control cell life and death. As when a highly connected node in the Internet breaks down, the disruption of p53 has severe consequences.



...

“One way to understand the p53 network is to compare it to the Internet. The cell, like the Internet, appears to be a ‘**scale-free network**’.”



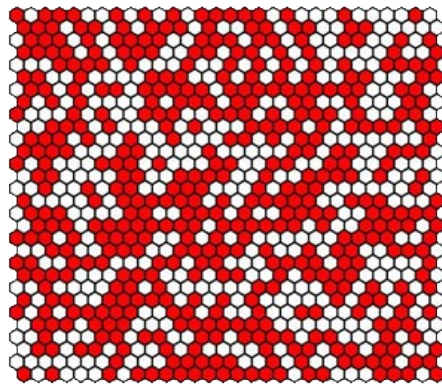
Pergunta comum: como falhas afetam o sistema?

Percolação:

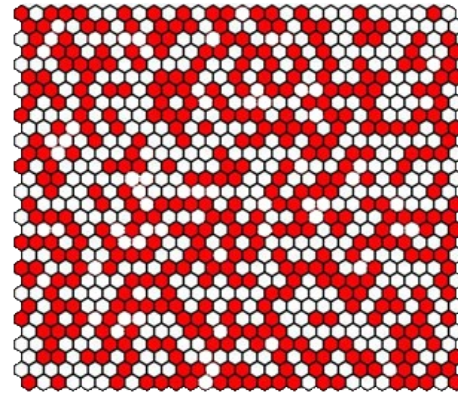
Sítios/ligações presentes com probabilidade p

Probabilidade de existência de aglomerado que atravessa sistema

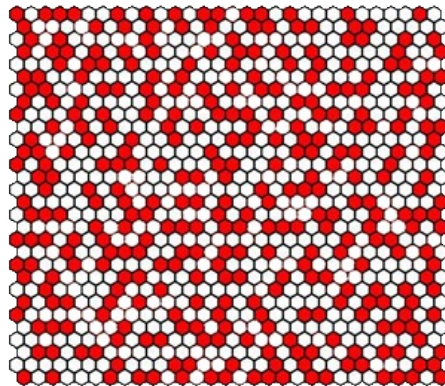
Transição de fase com/sem aglomerado percolante



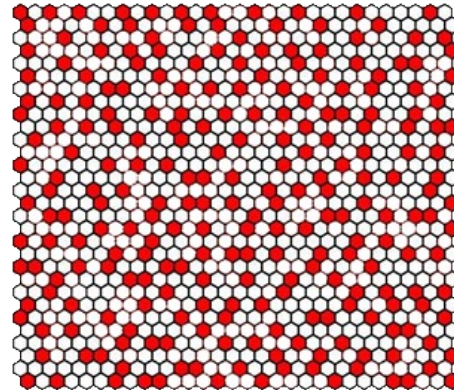
1. Red connected, white disconnected



2. Red partially connected, white partially disconnected



3. Red partially disconnected, white partially connected



4. Red disconnected, white connected

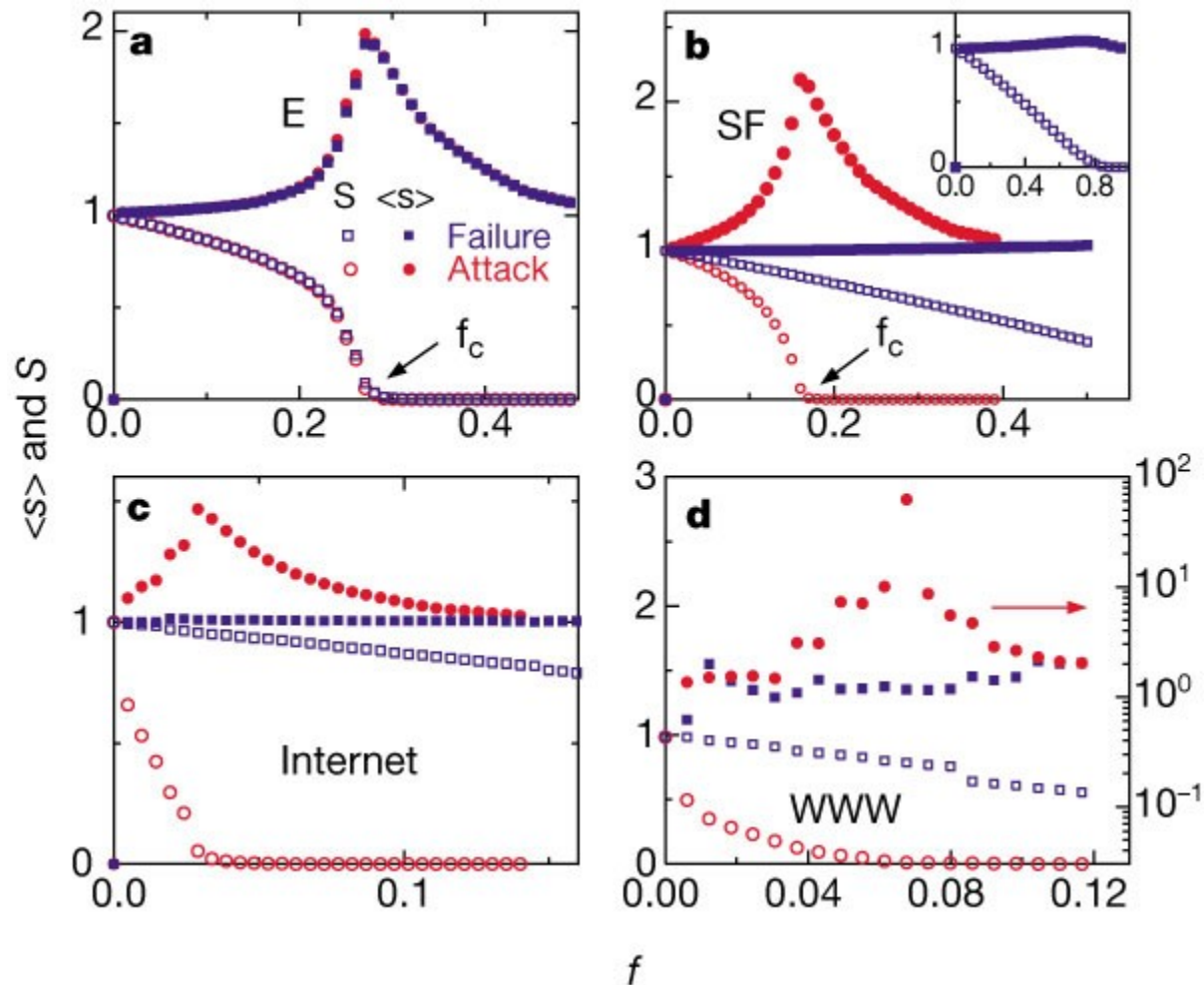
Pergunta comum: como falhas aleatórias afetam o sistema?

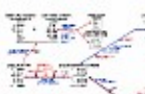
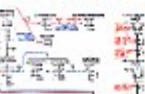
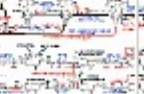
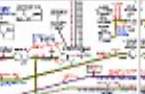
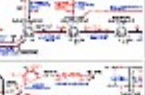
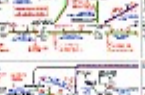
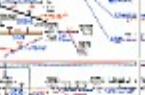
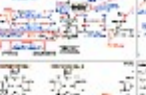
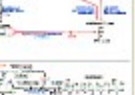
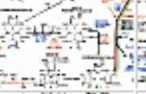
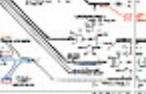
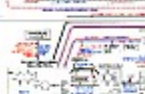
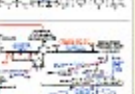
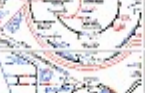
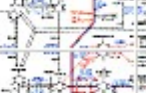
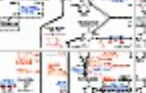
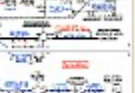
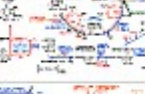
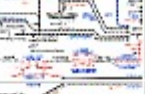
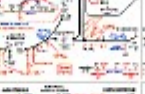
Percolação:

Sítios/ligações presentes com probabilidade p

Probabilidade de dois sítios quaisquer pertencerem ao mesmo aglomerado

Transição de fase com/sem aglomerado percolante



	A	B	C	D	E	F	G	H	I	J	K	L
1	Biochemical Pathways											
2												
3												
4												
5												
6												
7												
8												
9												
10												

Biochemical Pathways

1

2

3

4

5

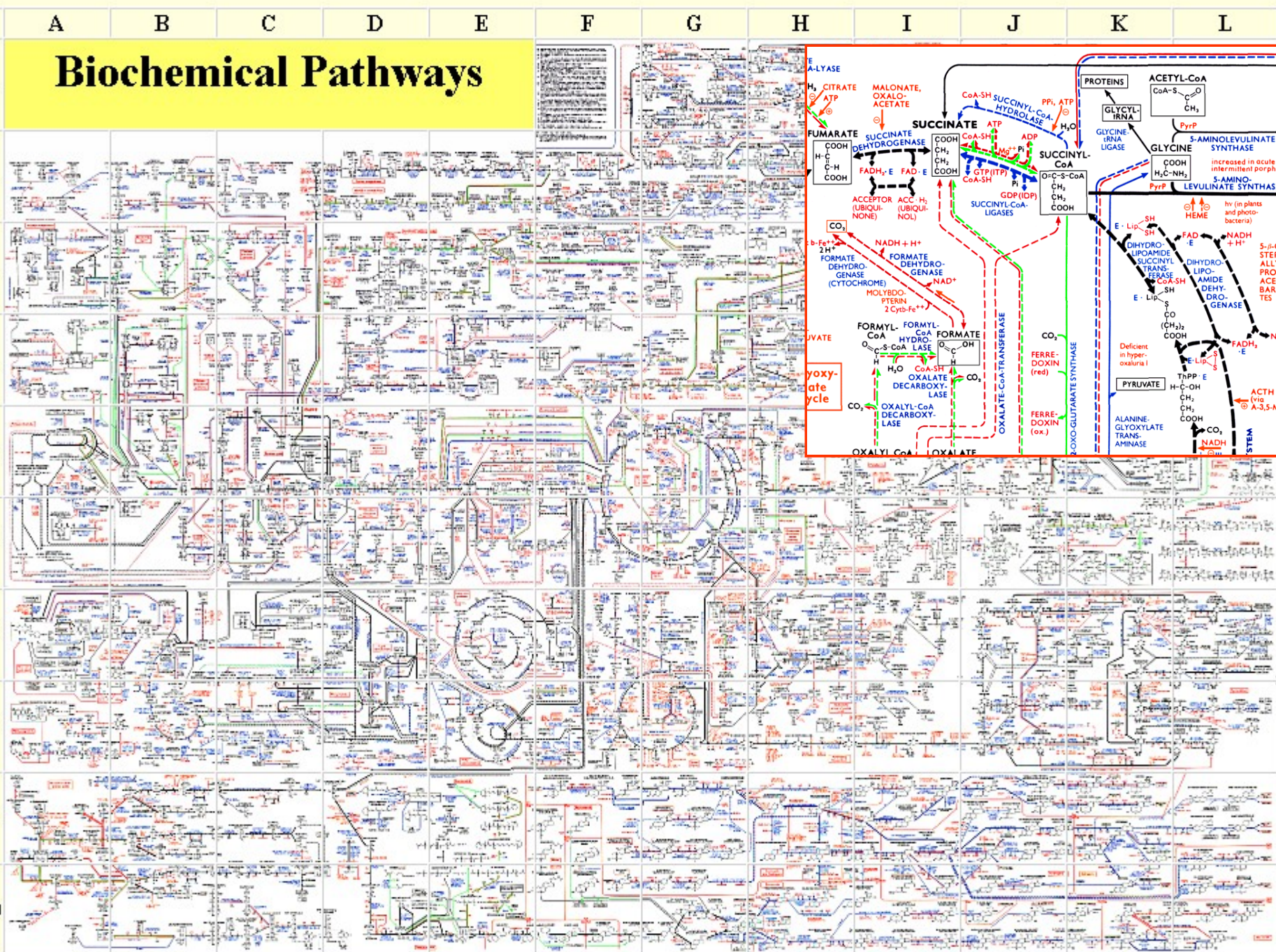
6

7

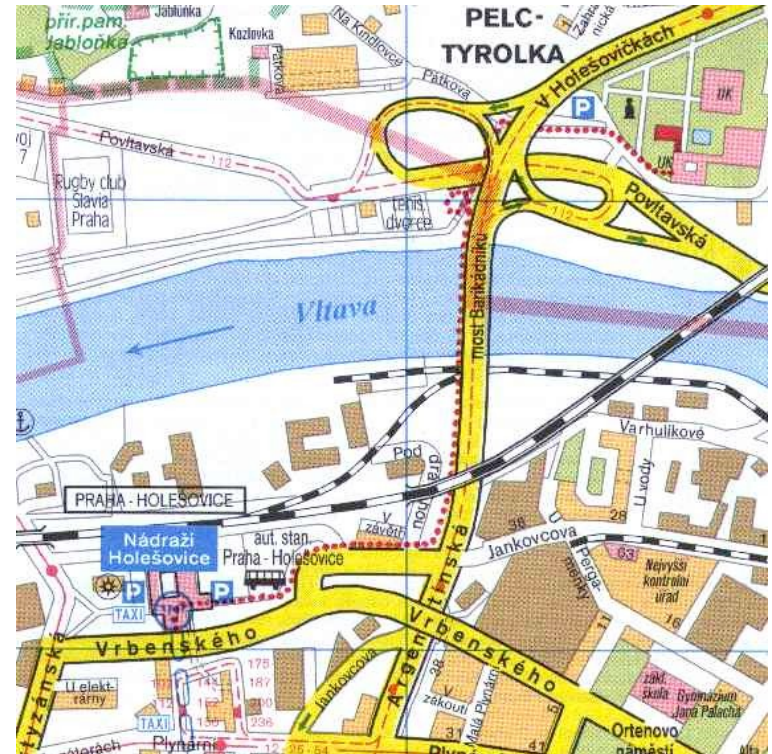
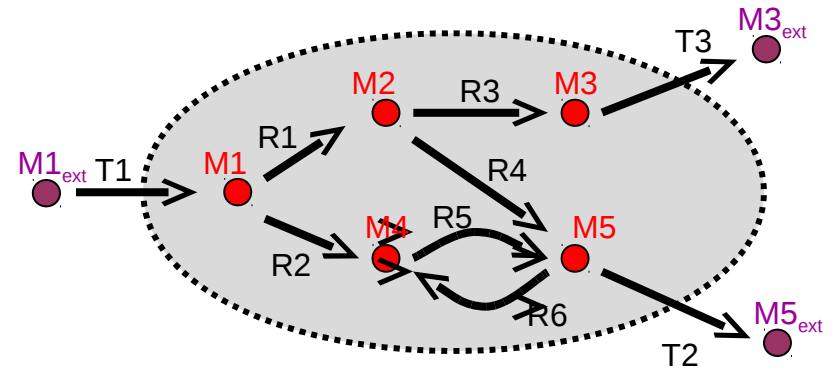
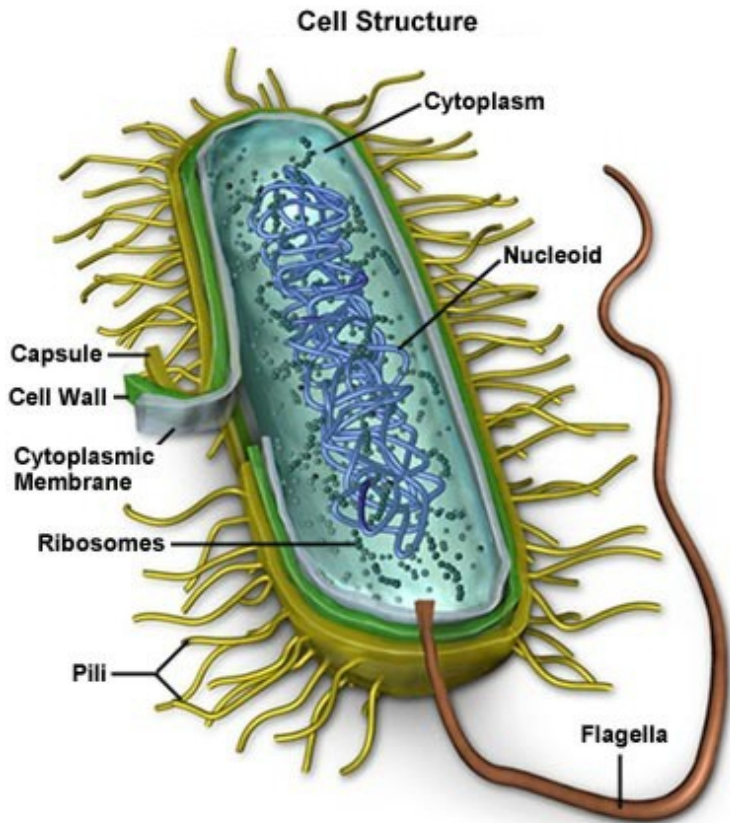
8

9

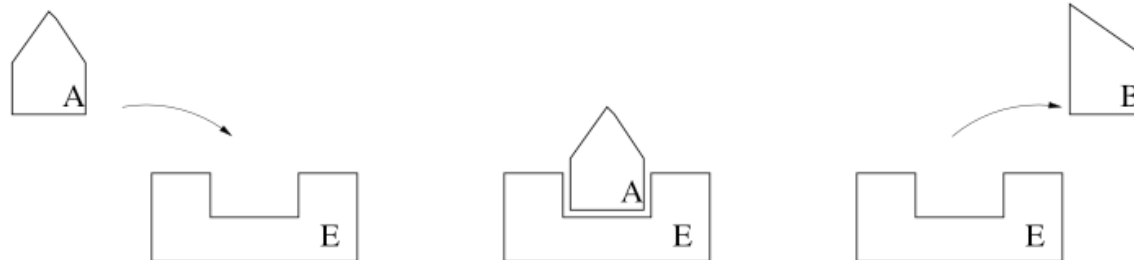
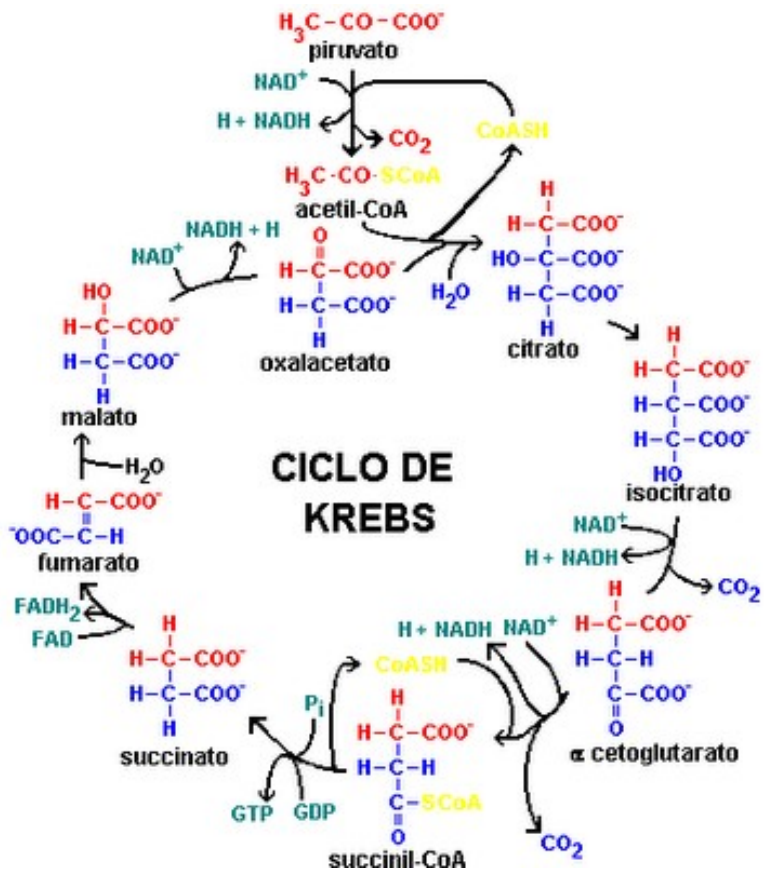
10



Metabolismo: fluxo de material celular

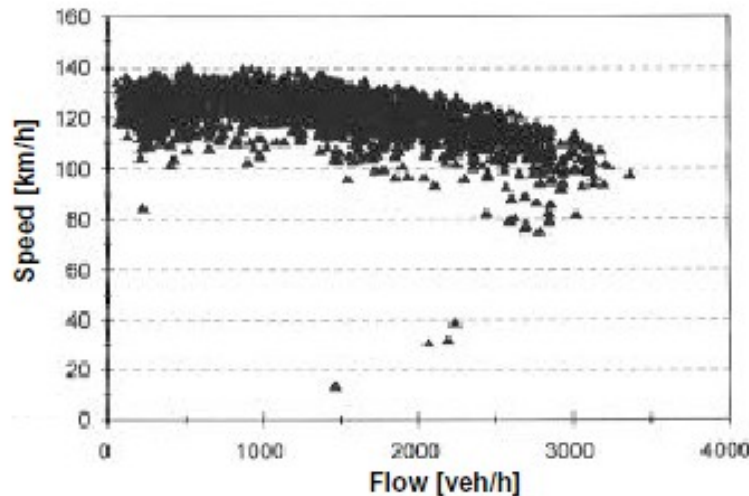


Metabolismo: fluxo de material celular

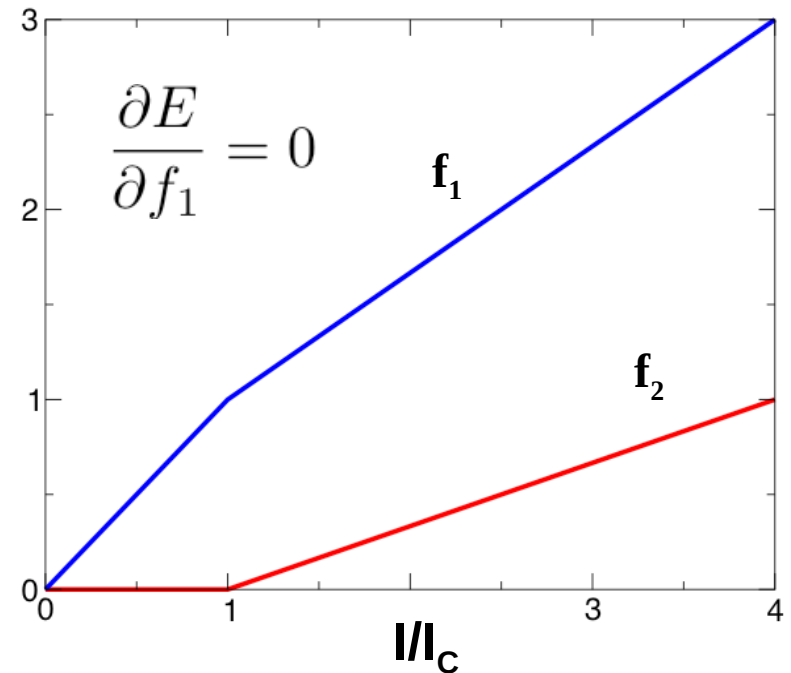
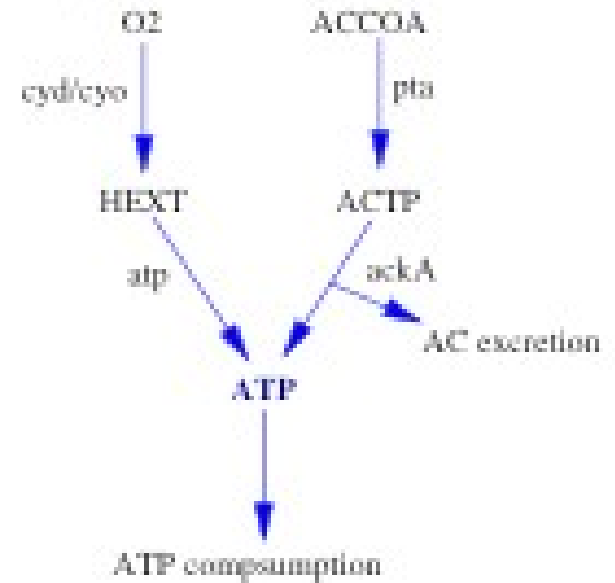


Tráfego em dois canais

- Estradas têm capacidade finita
- Engarrafamento
- Caminhos ótimos

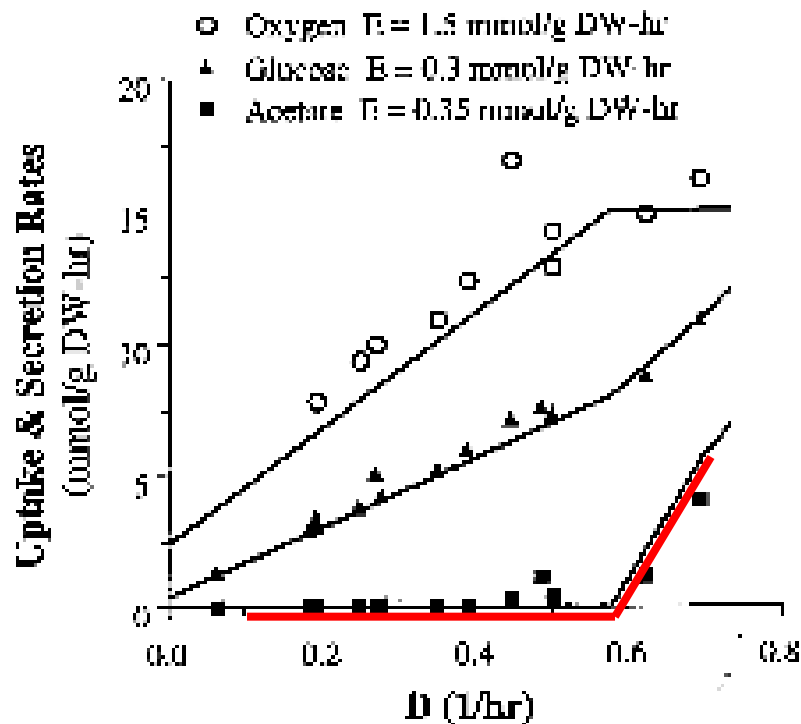


ATP generation

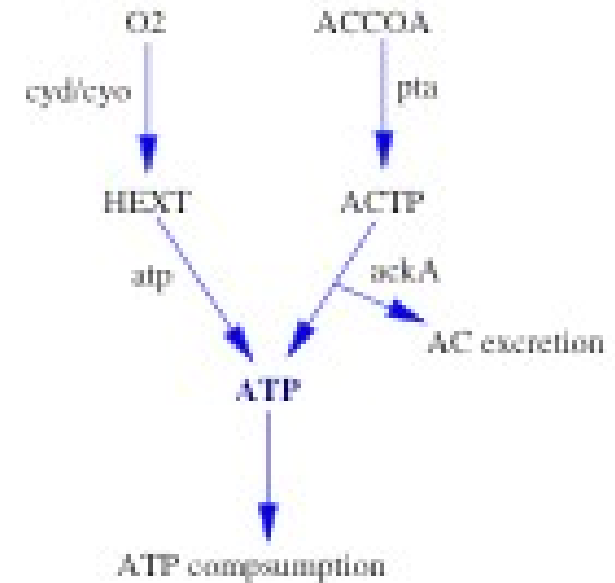


Metabolismo: consumo seletivo de nutrientes

- Auto-regulação genética funciona como controle de tráfego!
- Eficiência=capacidade reprodutiva
- Maior eficiência= menos enzimas



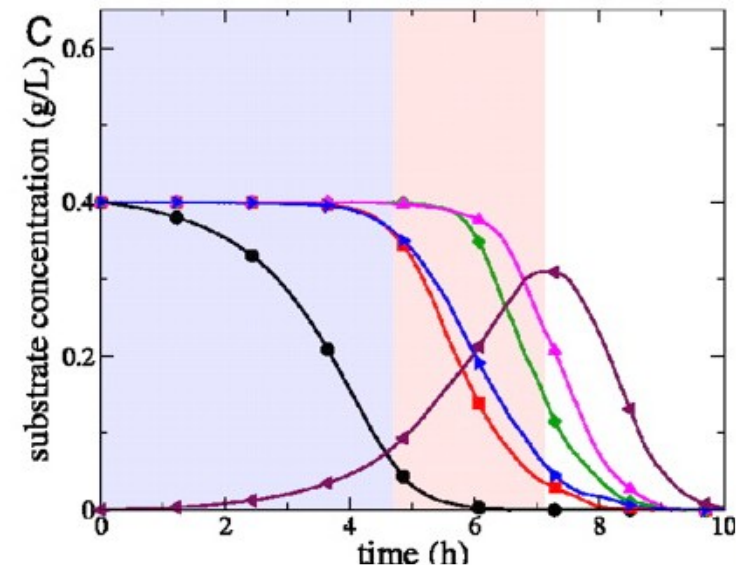
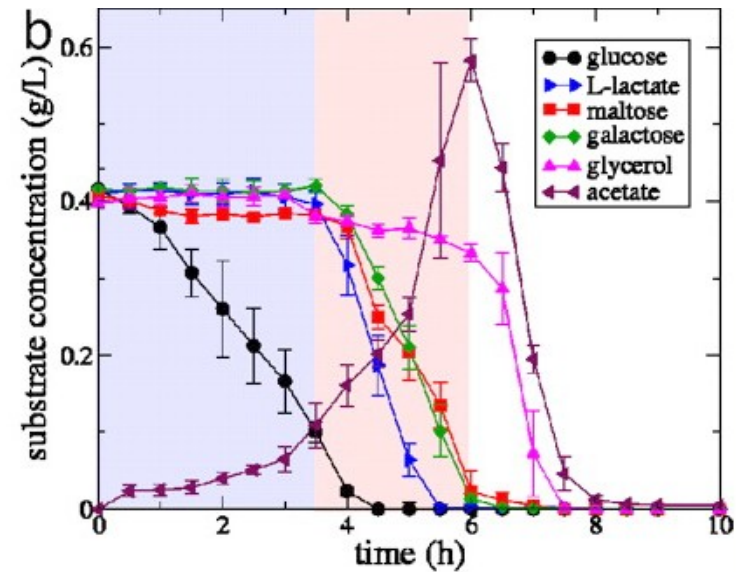
ATP generation



Metabolismo: fluxo seletivo de material celular

F. Jacob & J. Monod, "Genetic regulatory mechanisms in the synthesis of proteins"
J Mol Biol. 3: 318–56 (1961).

Q. K. Beg, A. Vazquez, J. Ernst,
M. A. de Menezes, Z. Bar-Joseph,
A.-L. Barabási and Z. N. Oltvai,
PNAS **104**, 12663 (2007)



- 1) Cite dois exemplos de sistemas que podem ser representados por uma rede, indicando os sítios e ligações
- 2) O que se estuda no problema de percolação
- 3) Cite um exemplo quotidiano de transição de fase