Networks

in biology

April 23, 2018

Birgit Sollie

VU VRIJE UNIVERSITEIT AMSTERDAM

NET WORKS

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Human body consists of cells

- Membrane
- Watery liquid

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Human body consists of cells

- Membrane
- Watery liquid

- About 50 thousand billion cells in our body
- More than half of our body is water
- Lung cells are 90% water
- Bone cells are only 10-20% water

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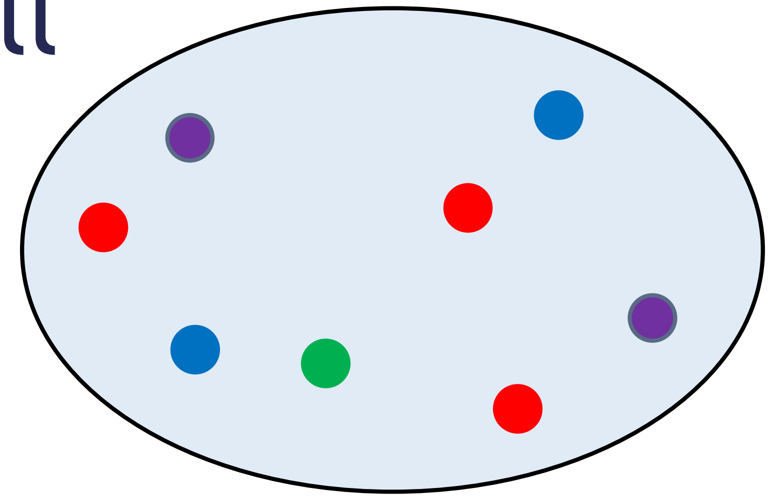
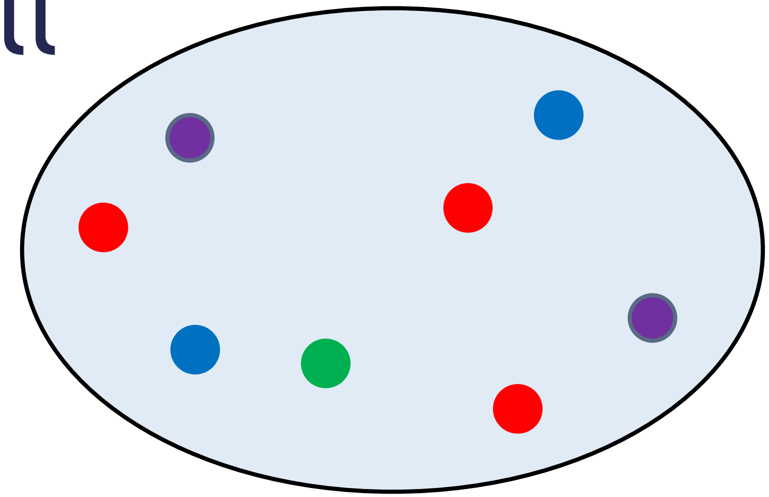
Molecules in the cell

- Nutrients
- Oxygen
- Proteins



Molecules in the cell



- Nutrients
- Oxygen
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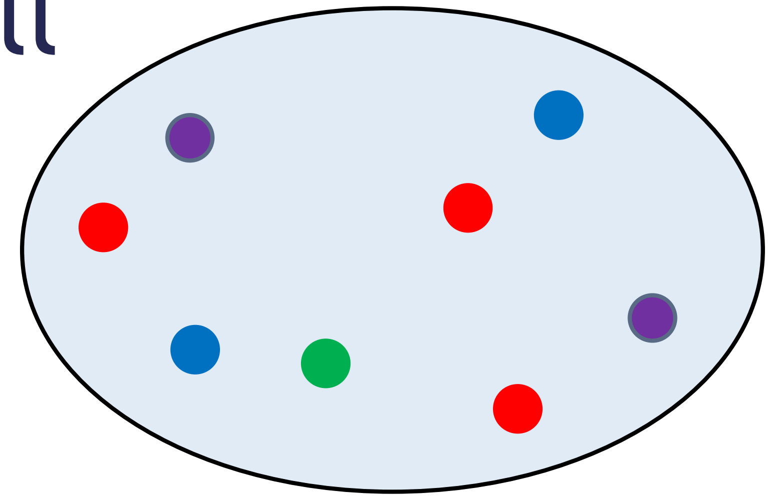
- Collision:
  - Stick together
  - Exchange
  - Nothing

Molecules in the cell



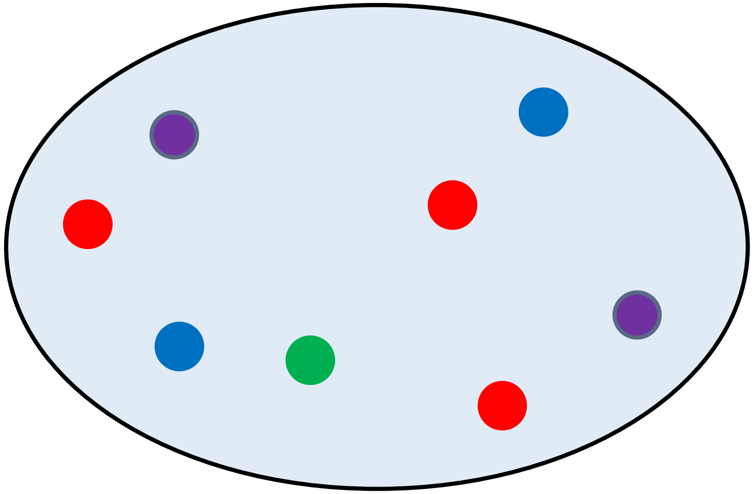
- Nutrients
- Oxygen
- Proteins

- Collision:
  - Stick together → Chemical reactions
  - Exchange → Chemical reactions
  - Nothing

Network of chemical reactions

Example
4 molecules: B,G,P and R

$$B + G \longrightarrow P$$
$$B + R \longrightarrow G$$
$$2P \longrightarrow R$$



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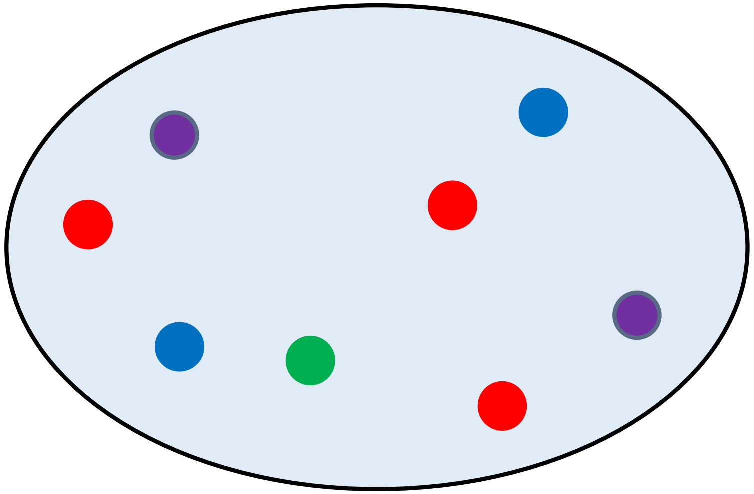

1 2 3

B G P R

Network of chemical reactions

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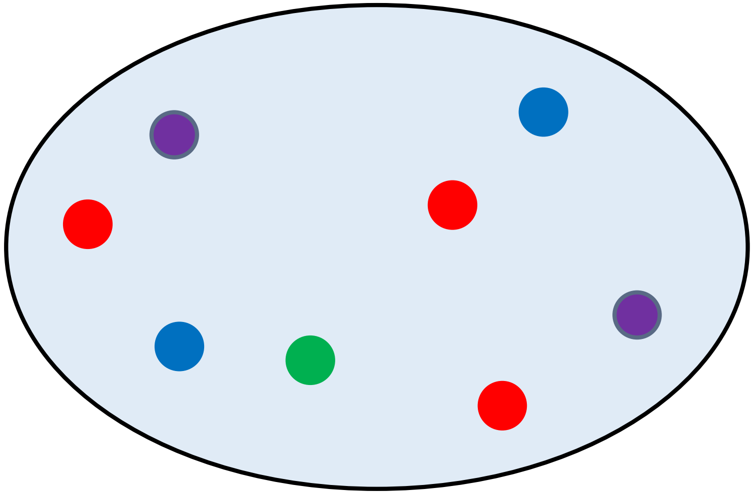

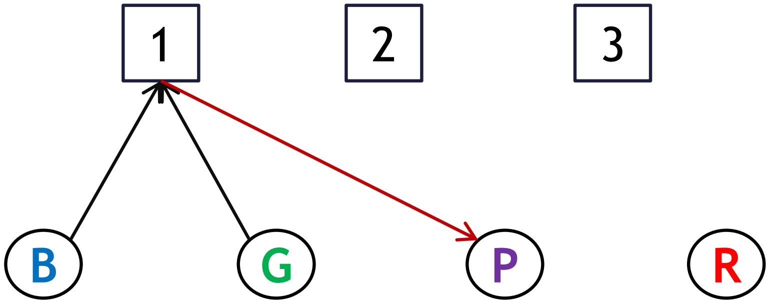

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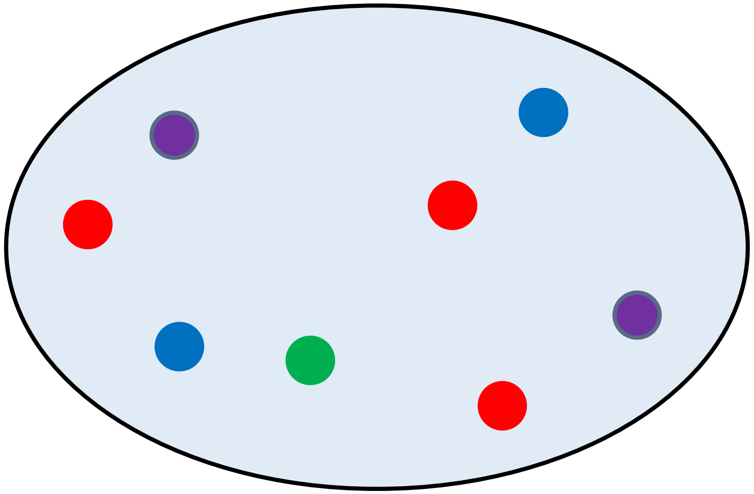

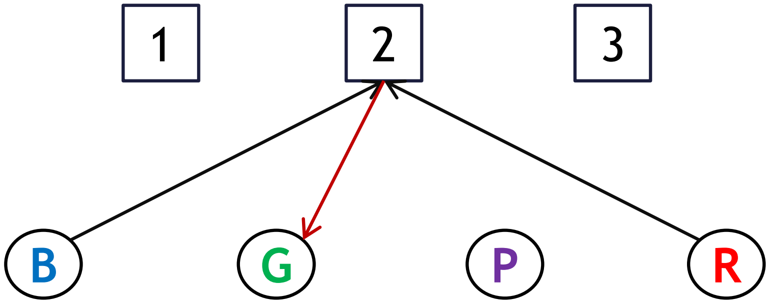

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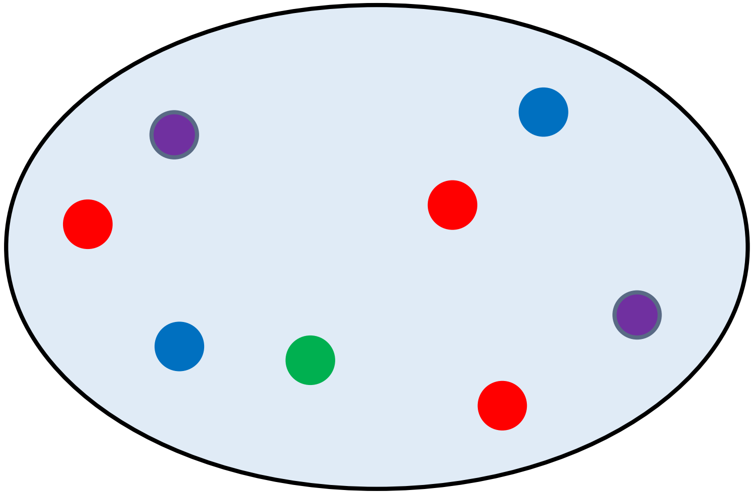

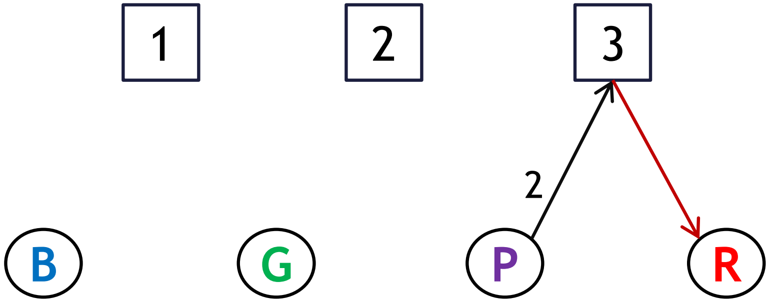

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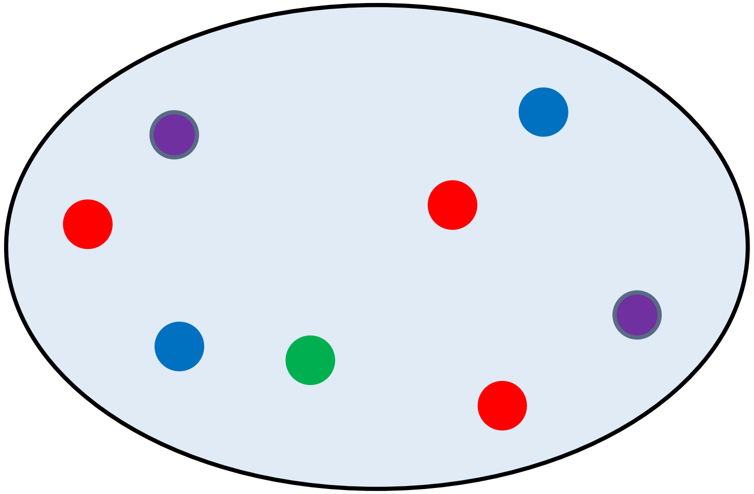

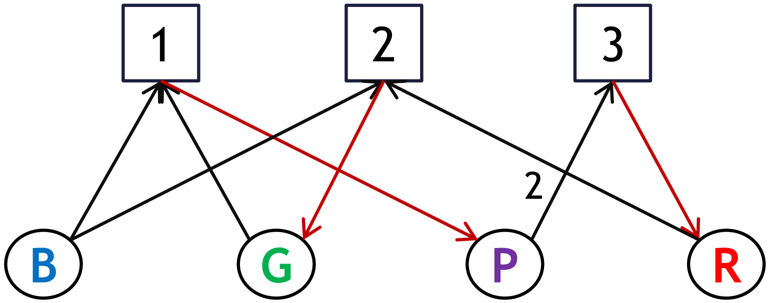

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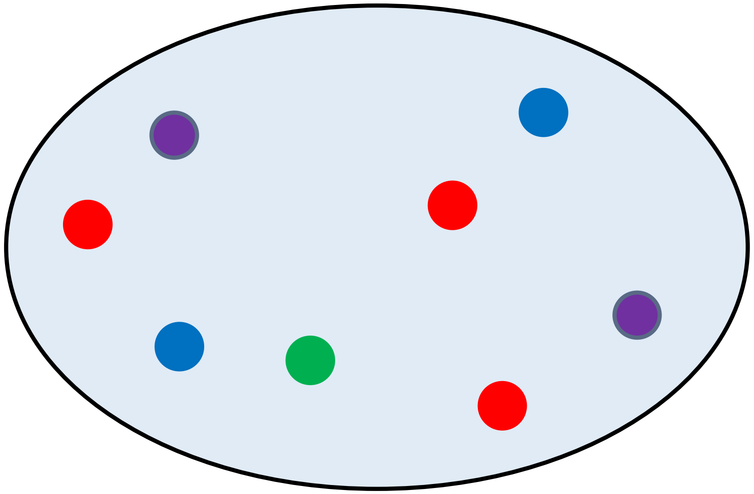
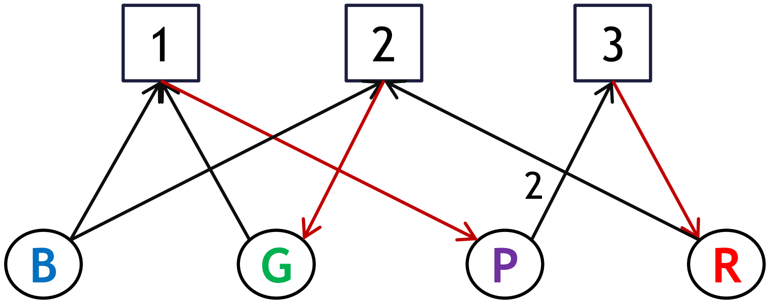
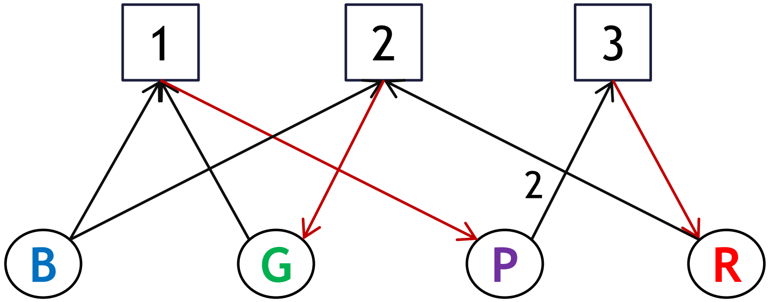




Directed bipartite network

The network

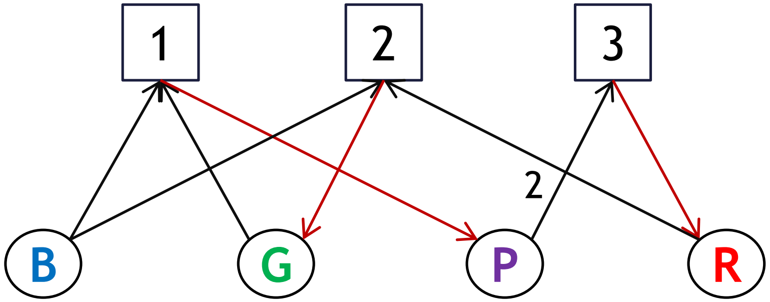
B + G $\longrightarrow$ P
B + R $\longrightarrow$ G
2P $\longrightarrow$ R



What is the best way to draw this network?

The network

B + G ⟶ P
B + R ⟶ G
2P ⟶ R



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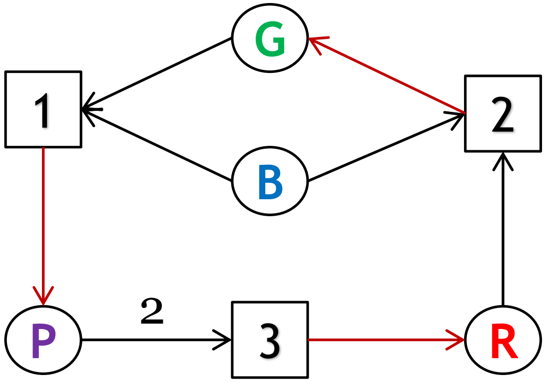
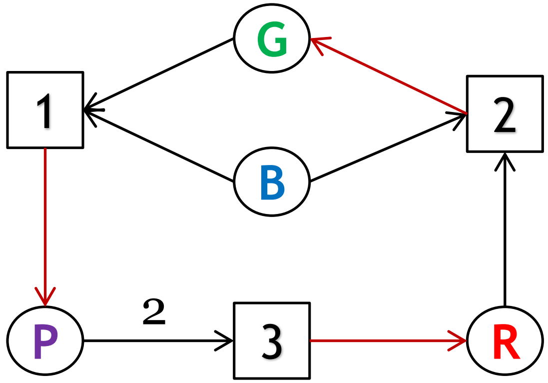


Probabilities

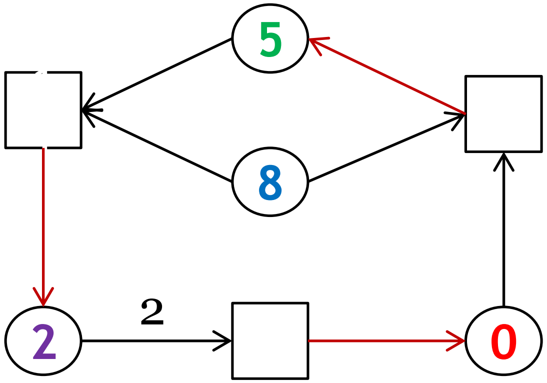


- The network is fixed
- Number of molecules changes over time

- Reactions take place with a certain probability

- These probabilities are often unknown
- But.. we want to know them!

Networks with numbers



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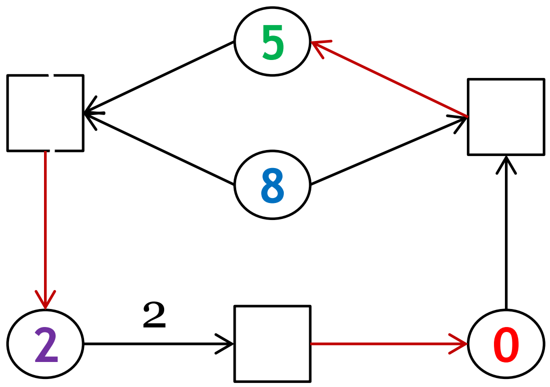

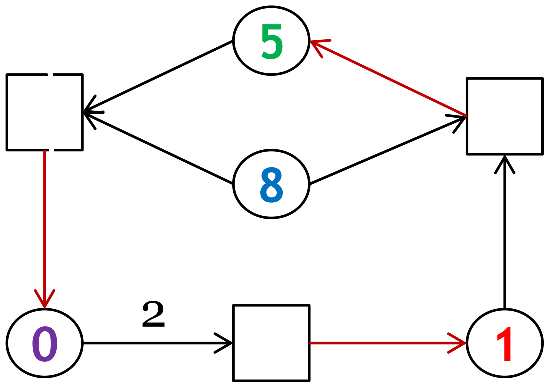

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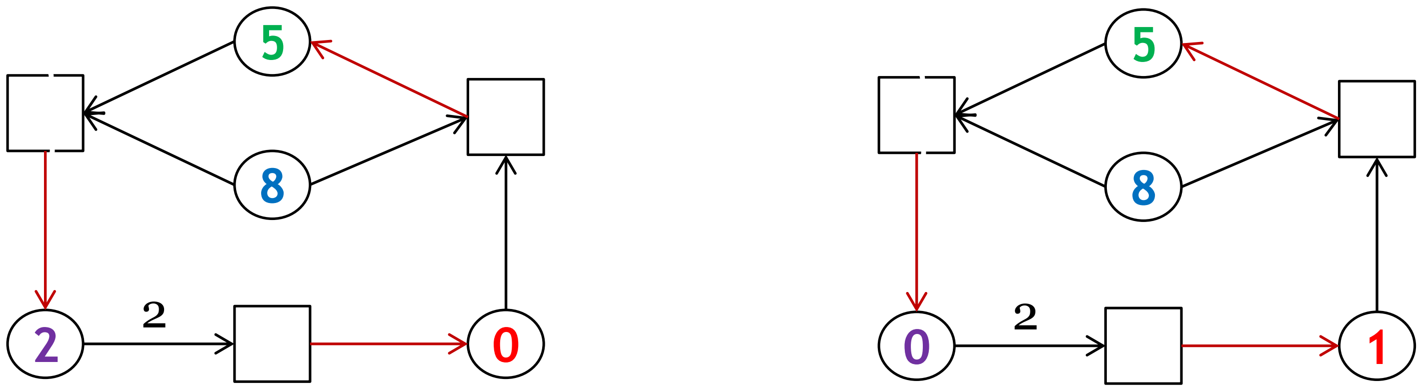

Which reaction took place here?

Statistics

- We constantly count the number of molecules in the cell
- (8,5,2,0) , (8,5,0,1) , …
- This is our data

- We can estimate the probabilities from the data

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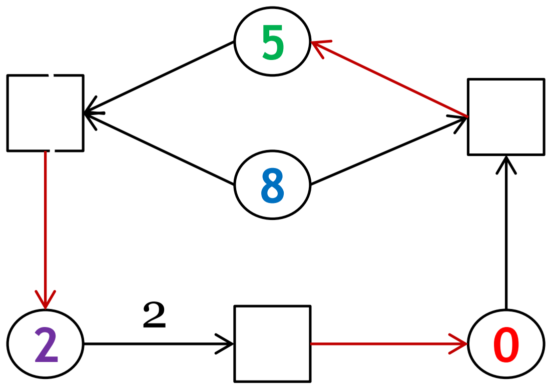
Networks with numbers



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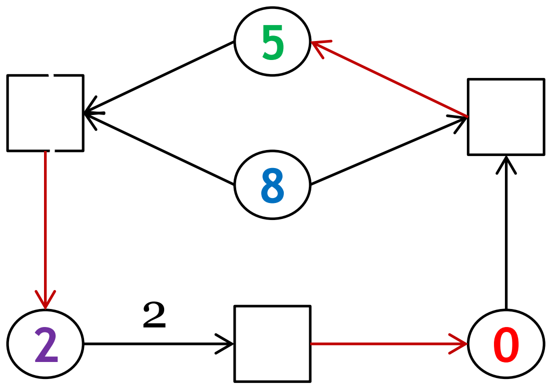

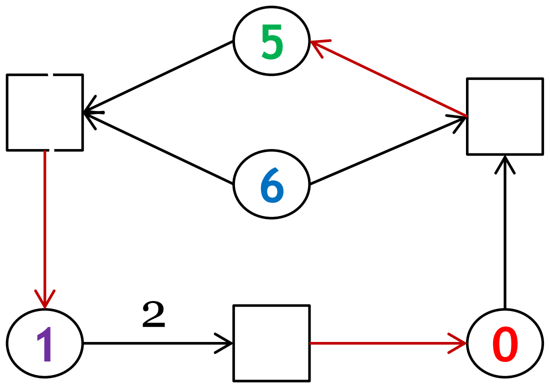

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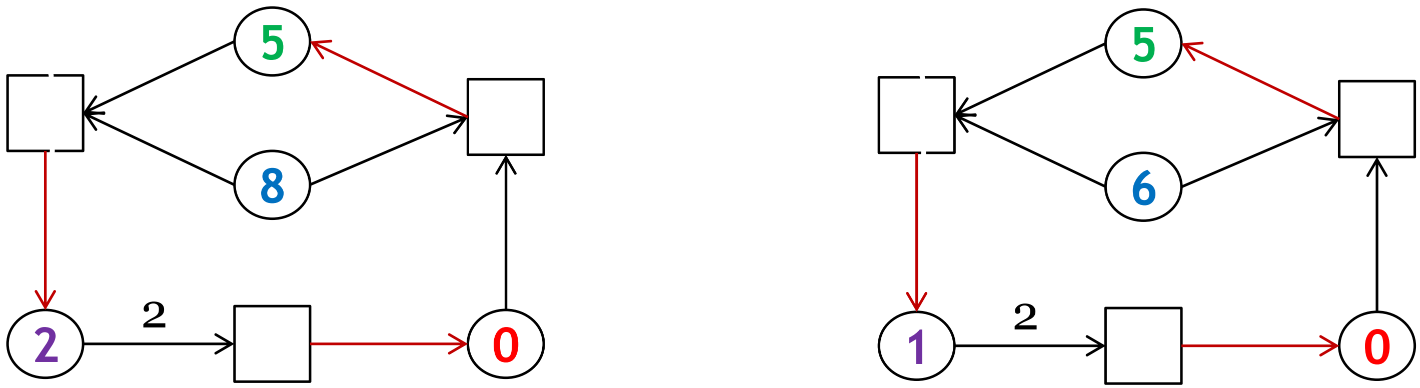
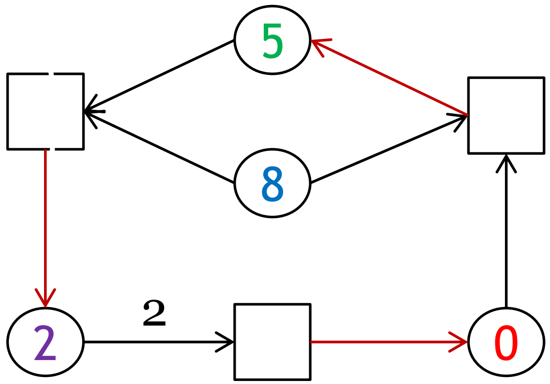


Which reactions took place, and how many?

Networks with numbers



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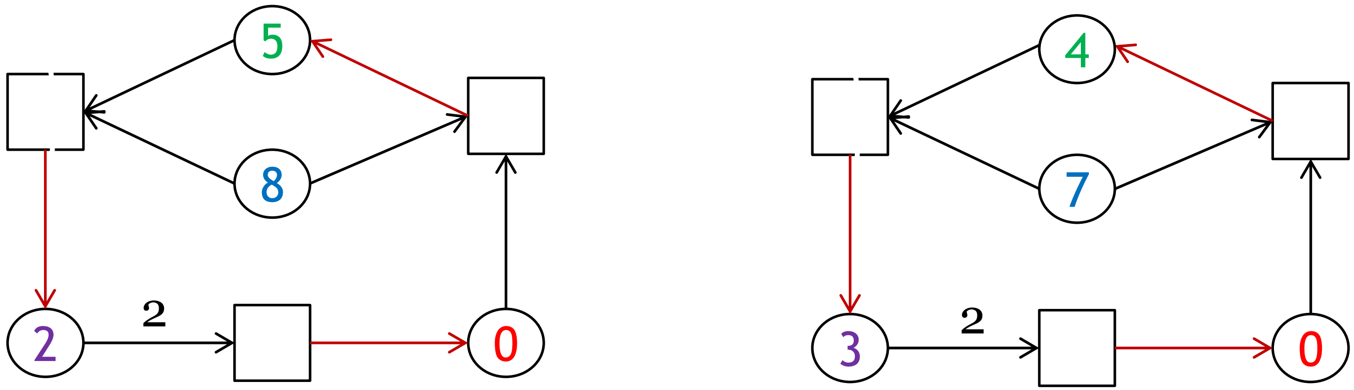

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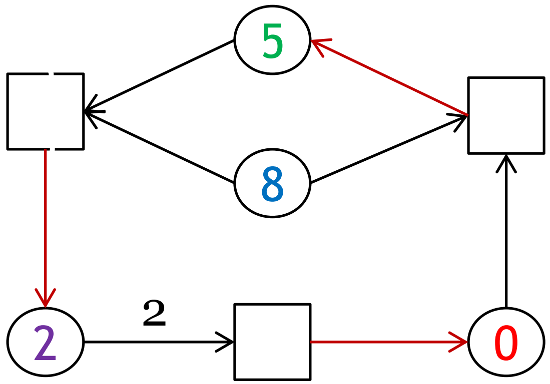

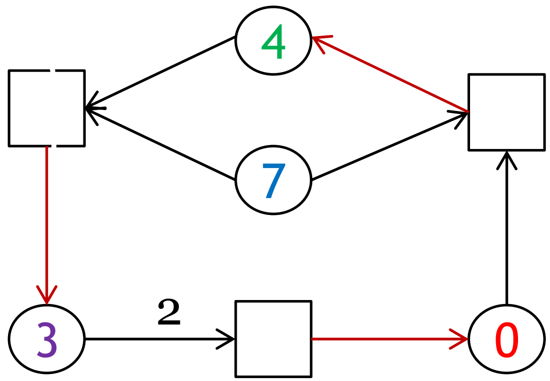

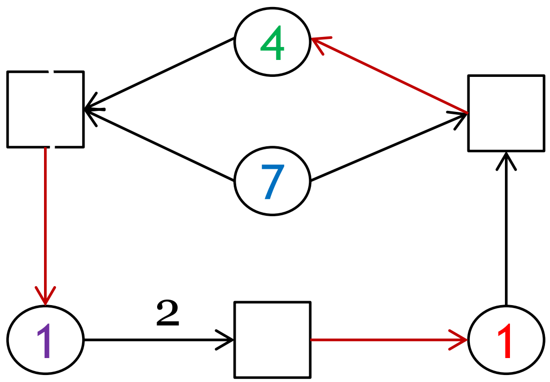

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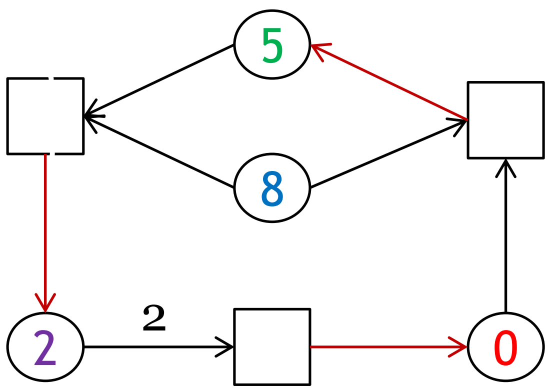
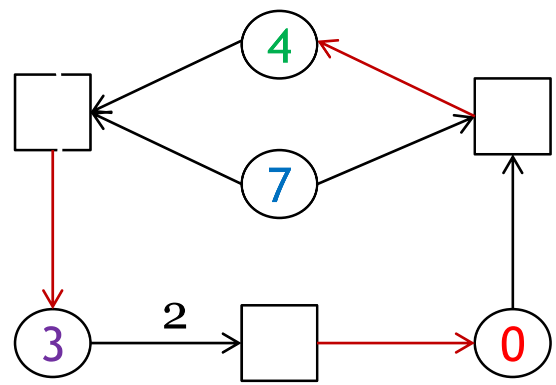
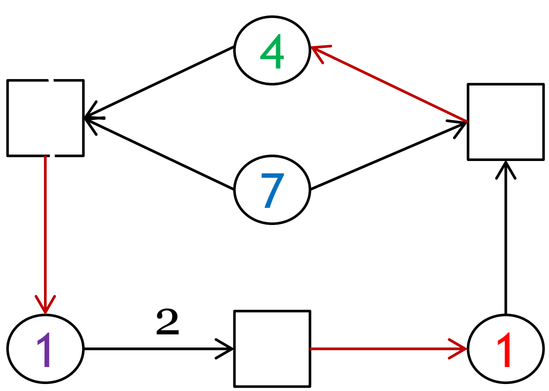
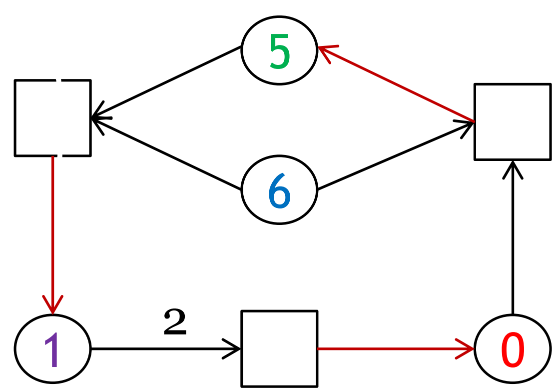
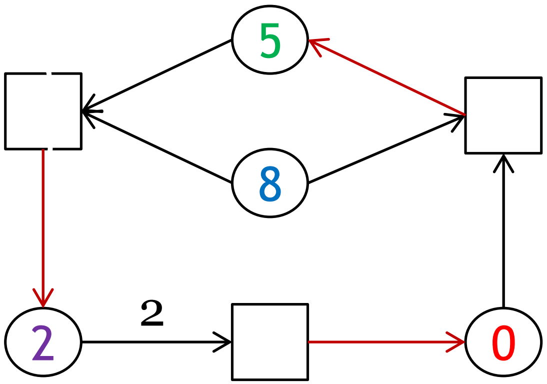








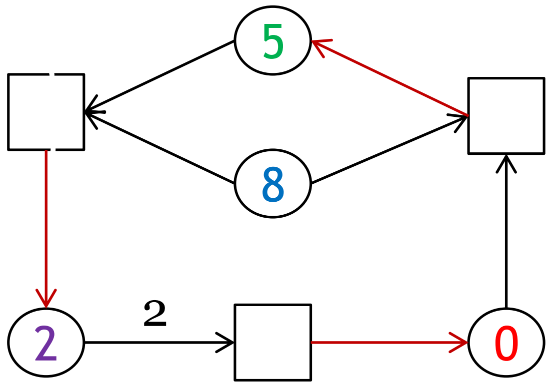
What will happen after a long time?



Equilibrium? Or will a molecule run out?

Matrix equation

$$\begin{aligned} B + G &\longrightarrow P \\ B + R &\longrightarrow G \\ 2P &\longrightarrow R \end{aligned}$$



- Out: $\begin{matrix} \mathbf{B} \\ \mathbf{G} \\ \mathbf{P} \\ \mathbf{R} \end{matrix} \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$, In: $\begin{matrix} \mathbf{B} \\ \mathbf{G} \\ \mathbf{P} \\ \mathbf{R} \end{matrix} \begin{pmatrix} 1 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 2 \\ 0 & 1 & 0 \end{pmatrix}$,

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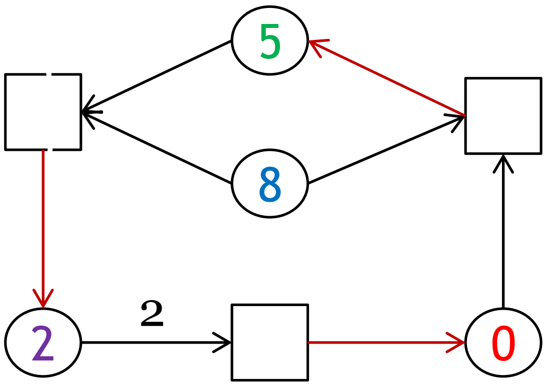

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Matrix equation

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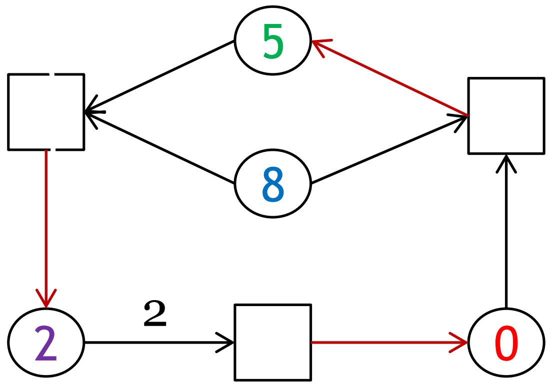

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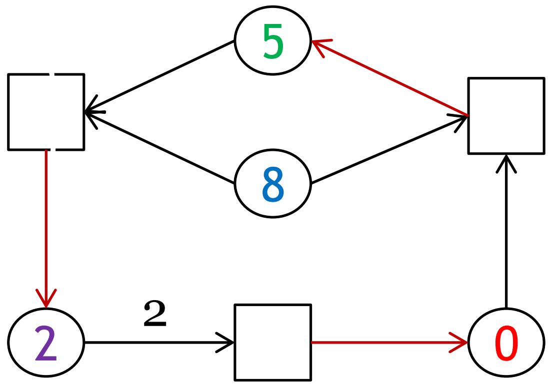
$$\begin{pmatrix} 8 \\ 5 \\ 2 \\ 0 \end{pmatrix} + \begin{pmatrix} \mathbf{-1} & \mathbf{-1} & \mathbf{0} \\ \mathbf{-1} & \mathbf{1} & \mathbf{0} \\ \mathbf{1} & \mathbf{0} & \mathbf{-2} \\ \mathbf{0} & \mathbf{-1} & \mathbf{1} \end{pmatrix} \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix} =$$

Matrix equation



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Out - In: $\begin{matrix} \mathbf{B} \\ \mathbf{G} \\ \mathbf{P} \\ \mathbf{R} \end{matrix} \begin{pmatrix} -1 & -1 & 0 \\ -1 & 1 & 0 \\ 1 & 0 & -2 \\ 0 & -1 & 1 \end{pmatrix}$

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Thank you!