Brainstorming Week on Membrane Computing (BWMC 2025)
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Computing by plasmids

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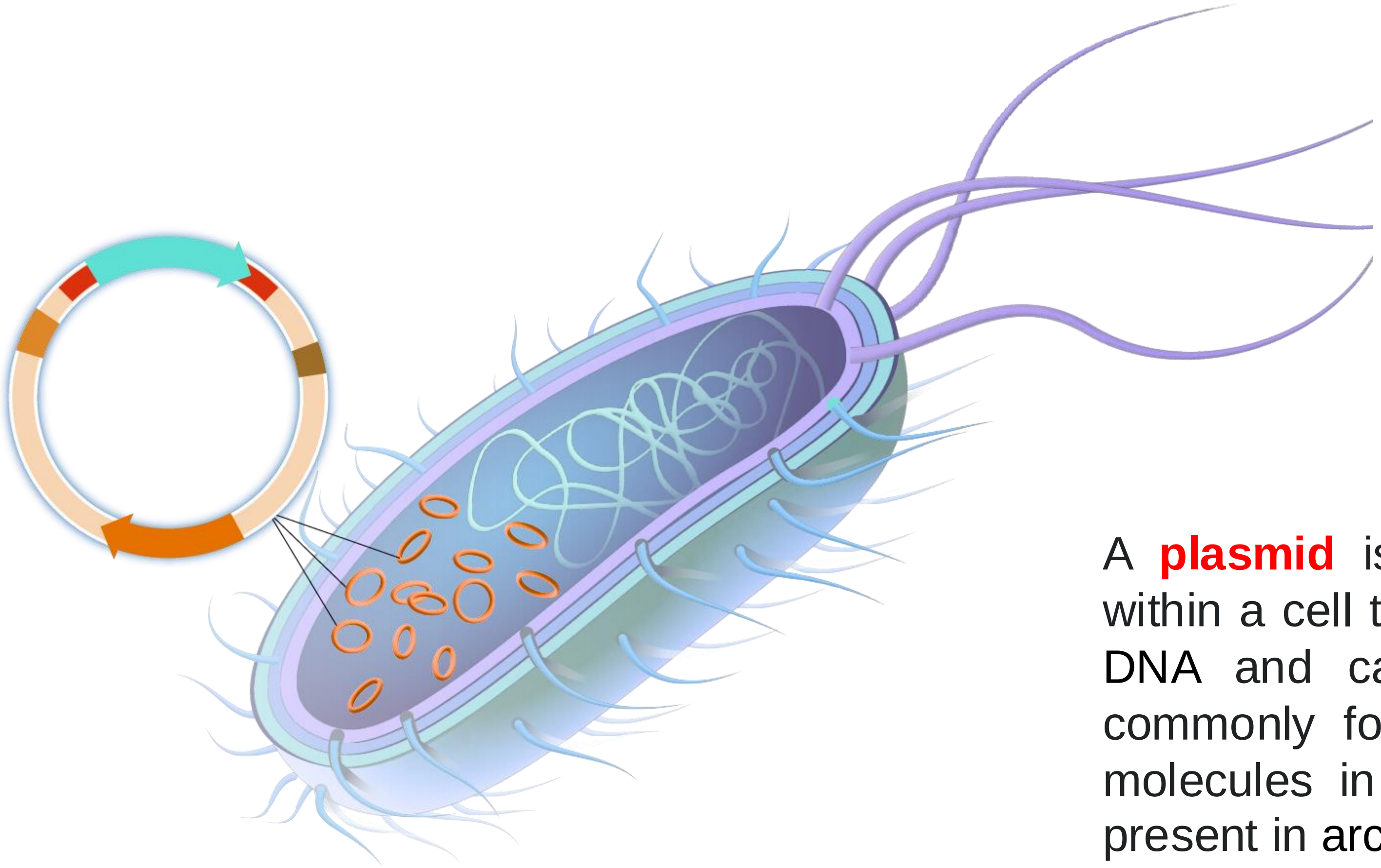


A **plasmid** is a small, extrachromosomal DNA molecule within a cell that is physically separated from chromosomal DNA and can replicate independently. They are most commonly found as small circular, double-stranded DNA molecules in bacteria; however, plasmids are sometimes present in archaea and eukaryotic organisms.

(Wikipedia)

Use plasmids to achieve movile/distributed computing and reduce the descriptional complexity of P systems

Related works

F.G.C. Cabarle, X. Zeng, N. Murphy, T. Song, A. Rodríguez-Patón, X. Liu. Neural-like P systems with plasmids. Information and Computation, Vol. 281, 194776. (2021)

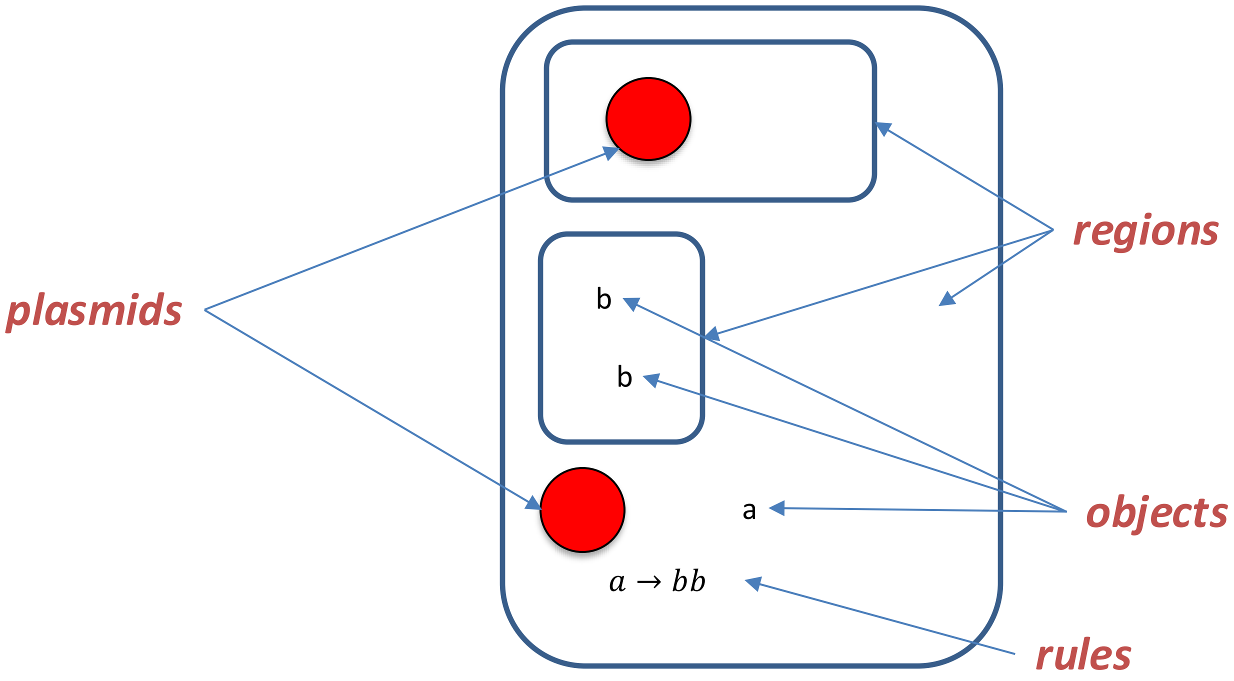
The authors introduce plasmid objects that have no explicit rules in the SP N framework

Y. Li, B. Song and X. Zeng. Neural-Like P Systems With Plasmids and Multiple Channels. IEEE Transactions on NanoBioscience, vol. 22, no. 2, (2023) 420-429

The authors combine plasmid objects that have no explicit rules and multiple channels in the SP N framework

What is a plasmid in the membrane computing framework ?

A **plasmid** is a finite set of rules (with priorities) that is surrounded by a membrane.



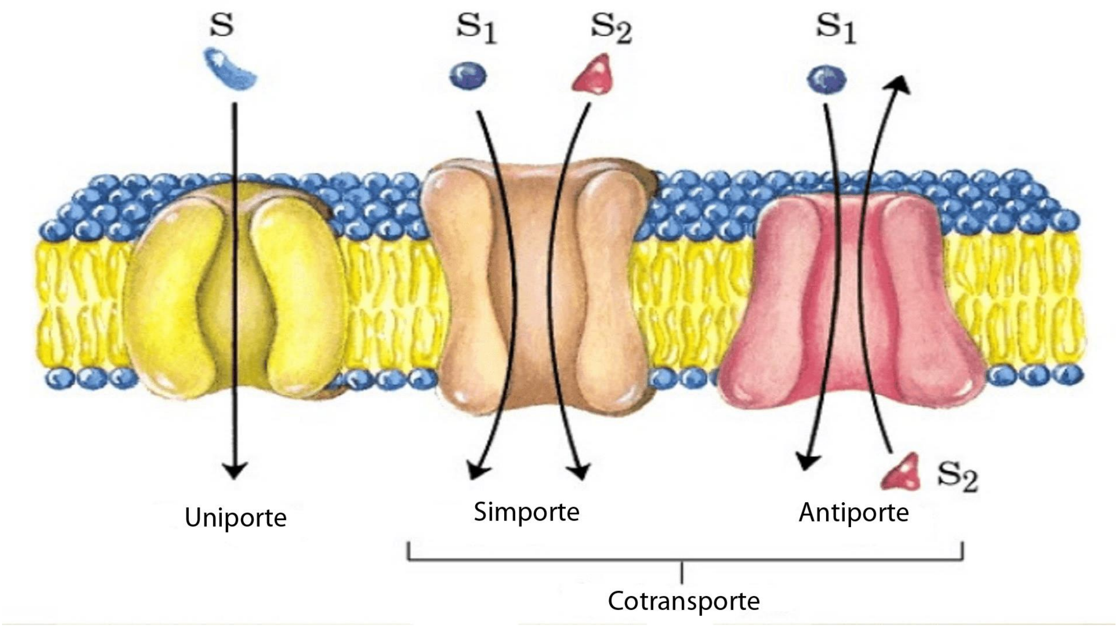
What operations can be made with plasmids ?

Plasmid mobility

'in symport': $p_i\, t[_k\, a]_k \rightarrow r[_k\, p_i\, b]_k$

'out symport': $t[_k\, p_i\, a]_k \rightarrow p_i\, r[_k\, b]_k$

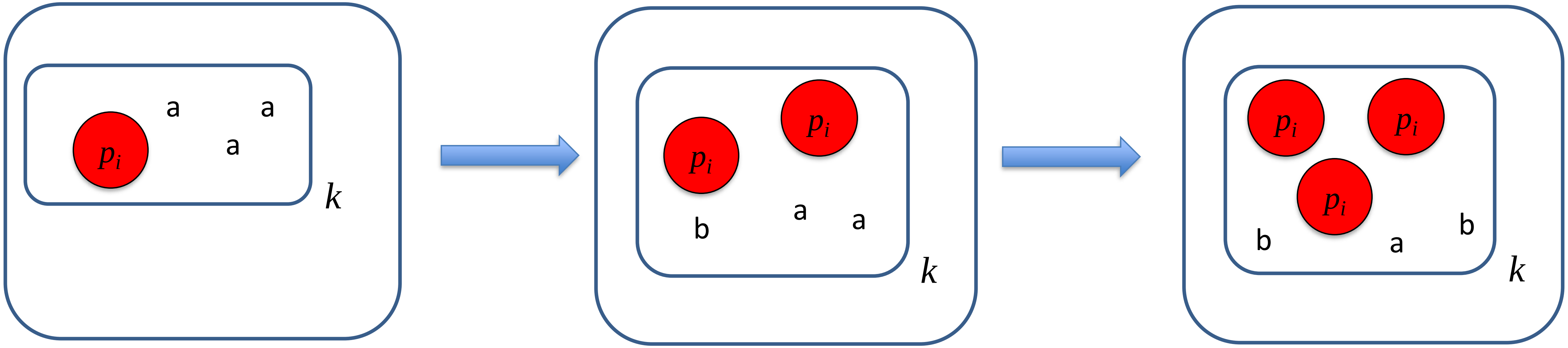
'anty-port': $p_i\, t[_k\, p_j\, a]_k \rightarrow p_j\, r[_k\, p_i\, b]_k$



What operations can be made with plasmids ?

Plasmid replication (initially, minimal paralellism occurrence, only one copy is produced)

$$[\, p_i \mathrm{a}]_k \rightarrow [p_i p_i b]_k$$



A P system with q plasmids of degree $m \geq 1$ (Ppl_m^q) is defined by

$$\Pi = (V, H, \mu, w_1, w_2, \dots, w_m, R_o, R_p, \sigma, z_1, z_2, \dots, z_m, z_\infty, p_1, p_2, \dots, p_q, i_0)$$, where:

1) V is an alphabet of objects.
2) H is an alphabet of membrane labels.
3) μ is a membrane estructure.
4) $\mathrm{w}_1, \mathrm{w}_2, \dots, \mathrm{w}_\mathrm{m}$ are the initial multisets of objects at every region.
5) R_o is a set of rules for objects and membranes.
6) R_p is a set of rules for plasmid mobility and plasmid replication.
7) σ is a partial order over R_0 and R_p.
8) $z_1, z_2, \dots, z_m, z_\infty$ are the initial multisets of plasmids at every region and the environment.
9) $p_1, p_2, \dots, p_q$ are plasmids, where every plasmid is defined by a finite set of rules for objects.
10) $i_0 \in \{1, \dots, m\} \cup \infty$ is the output membrane.

Remarks

- Initially plasmid rules only affect to objects (they do not affect to plasmids or membranes)
- Initially we only allow plasmid mobility and replication (no plasmid destruction)
- Plasmid replication is applied with minimal parallelism occurrence (only applied to one copy).

An example

$P_1 : \{a \rightarrow a_{out}\}$

$P_2 : \{ab \rightarrow c_{out}\}$

$R_o : [\, a\, [\ ]_3\,]_1 \rightarrow [\ [\, a\,]_3\,]_1$

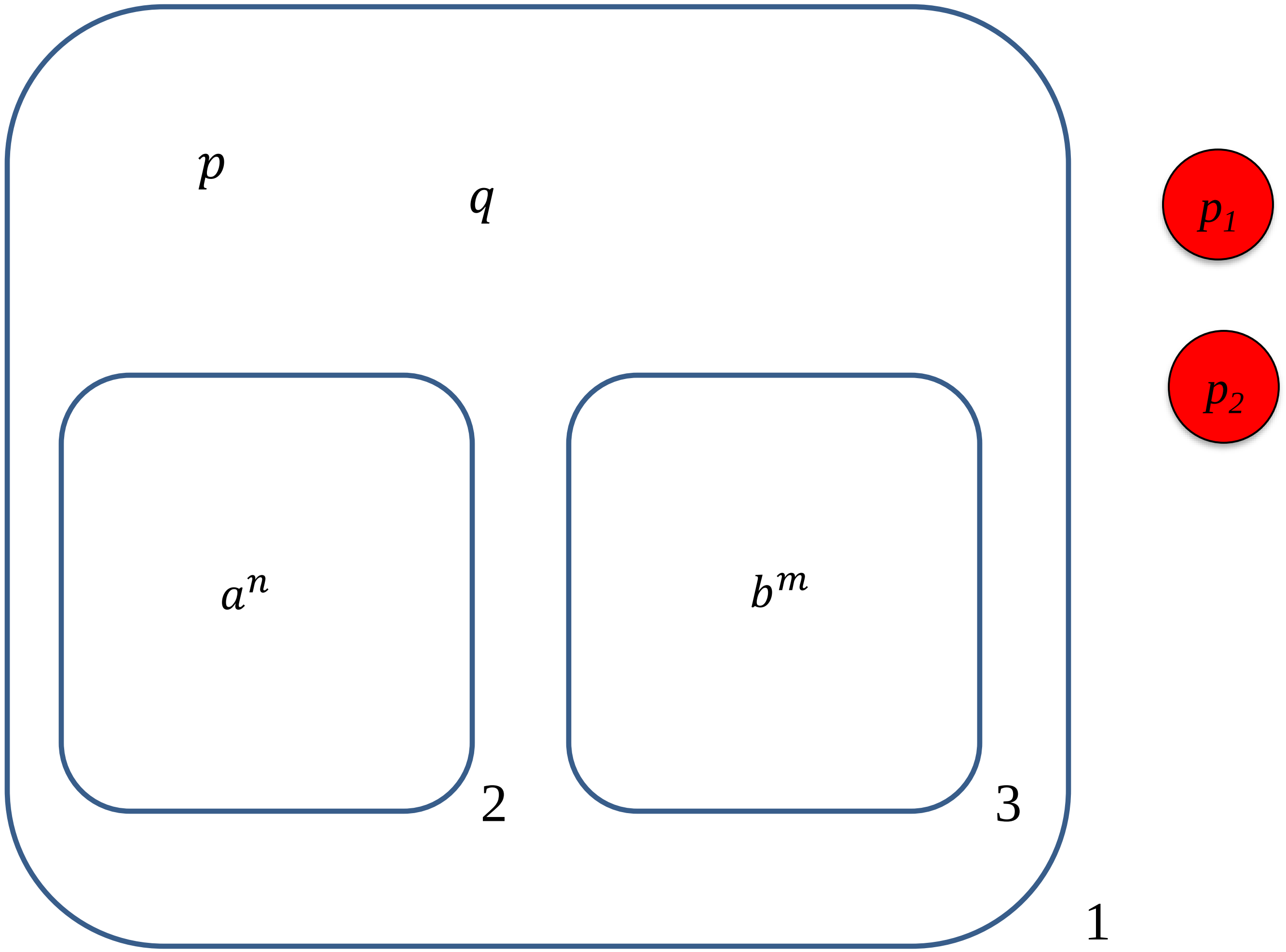
$R_p :$

$P_1 [\, p\,]_1 \rightarrow [\, P_1\,]_1$

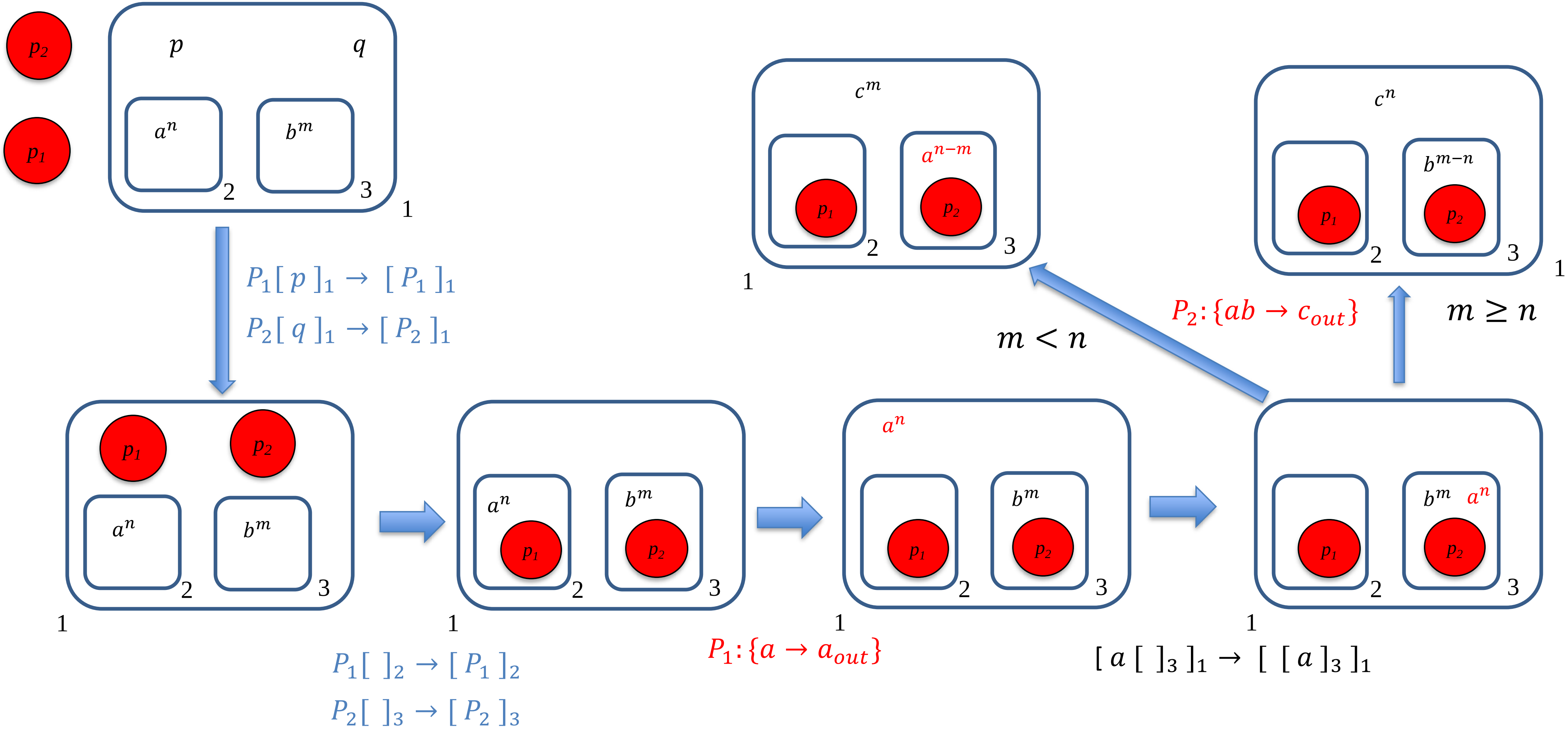
$P_2 [\, q\,]_1 \rightarrow [\, P_2\,]_1$

$P_1 [\ ]_2 \rightarrow [\, P_1\,]_2$

$P_2 [\ ]_3 \rightarrow [\, P_2\,]_3$



An example


p_2
p_1
p
q
a^n
b^m
2
3
1
$P_1[\ p\ ]_1 \rightarrow [\ P_1\ ]_1$
$P_2[\ q\ ]_1 \rightarrow [\ P_2\ ]_1$
$P_1[\ ]_2 \rightarrow [\ P_1\ ]_2$
$P_2[\ ]_3 \rightarrow [\ P_2\ ]_3$
$P_1 : \{a \rightarrow a_{out}\}$
$[\ a\ [\ ]_3\ ]_1 \rightarrow [\ [\ a\ ]_3\ ]_1$
$P_2 : \{ab \rightarrow c_{out}\}$
$m < n$
$m \geq n$
c^m
a^{n-m}
c^n
b^{m-n}

Universality

A natural way to simulate register machines:

- Every basic instruction is a plasmid
- Every register is a membrane inside the skin membrane
- The program runs through plasmid mobility
- The instruction counter is defined by a specific set of objects related to the register machine instruction labels.

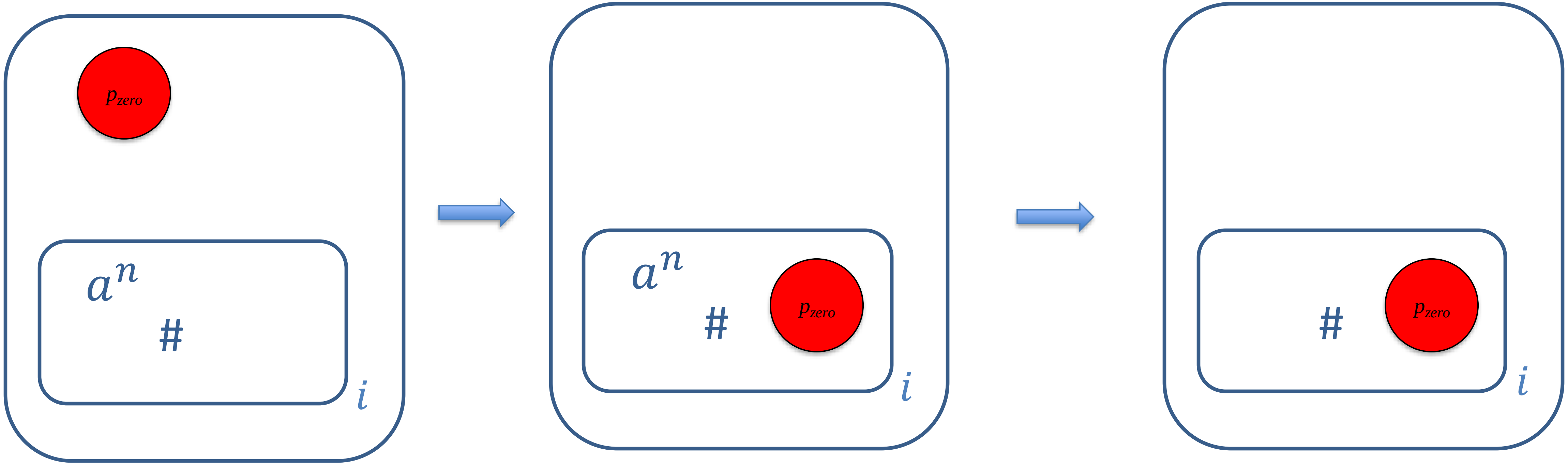
Let us suppose that we encode $n \in \mathbb{N}$ as $a^n\#$

$zero(i)$

$[\, i \,] \leftarrow 0$

$P_{zero}[\ ]_i \rightarrow [\, P_{zero}\,]_i$

$P_{zero} = \{a \rightarrow \lambda\}$

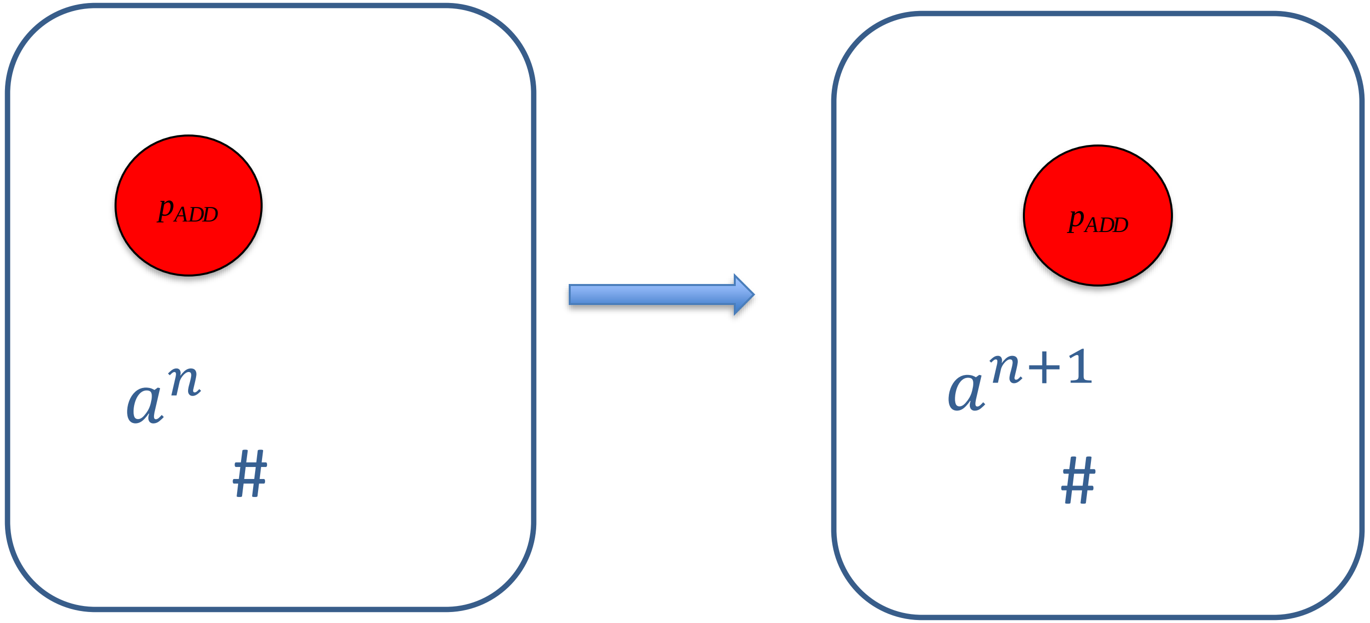


Let us suppose that we encode $n \in \mathbb{N}$ as $a^n\#$

$\mathrm{ADD}(i, l_1, l_2)$

$[\, i \,] \leftarrow [i] + 1$

$$P_{ADD} = \{a\# \rightarrow aa\#\}$$

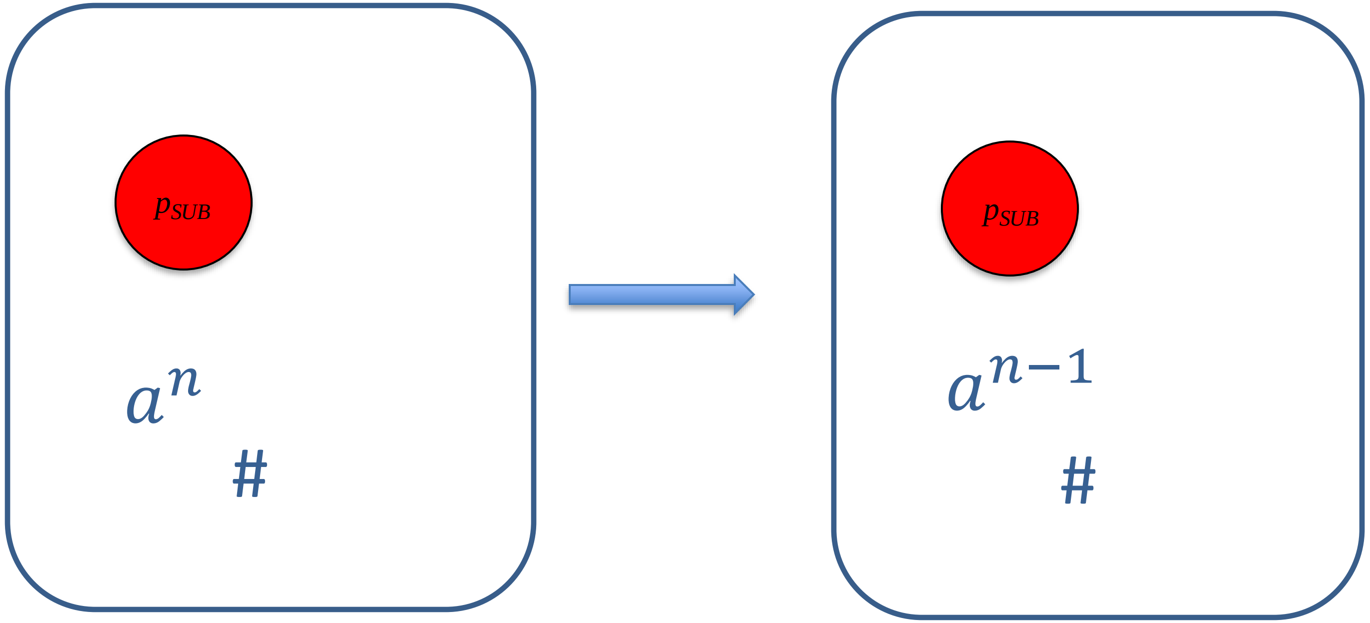


Let us suppose that we encode $n \in \mathbb{N}$ as $a^n\#$

$\mathrm{SUB}(i, l_1, l_2)$

$[\,i\,] \leftarrow [i] - 1$

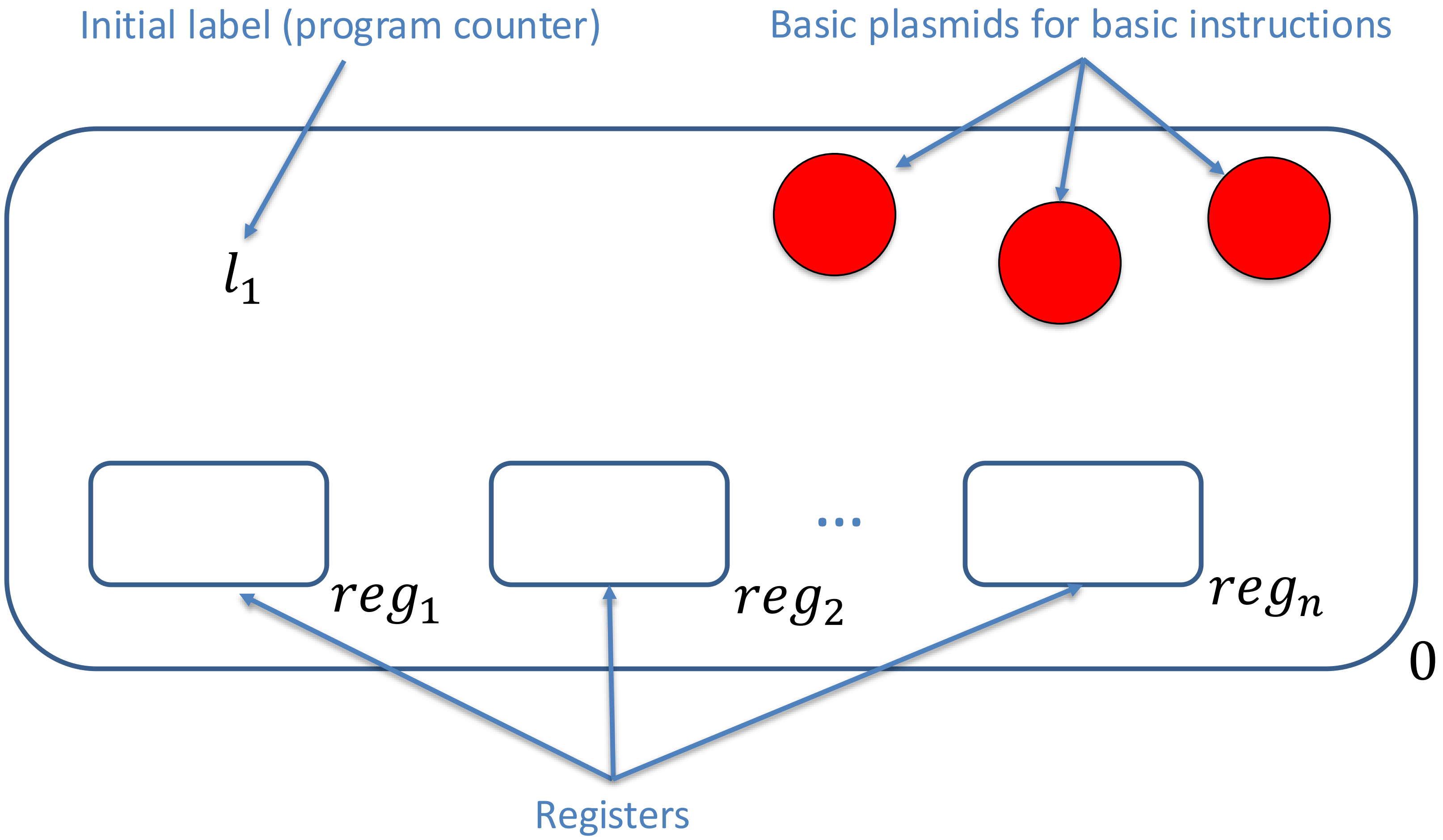
$P_{SUB} = \{a\# \rightarrow \#\}$



$n > 0$

The execution of a program with n registers

l_1: instruction1
l_2: instruction2
...
l_p: instruction$p$



The execution of a program with n registers

l_1:ADD(i, l_2, l_3)

Execution init

$[l_1 P_{ADD} [\ ]_i]_0 \to [\,[\,l_1 P_{ADD}]_i]_0$

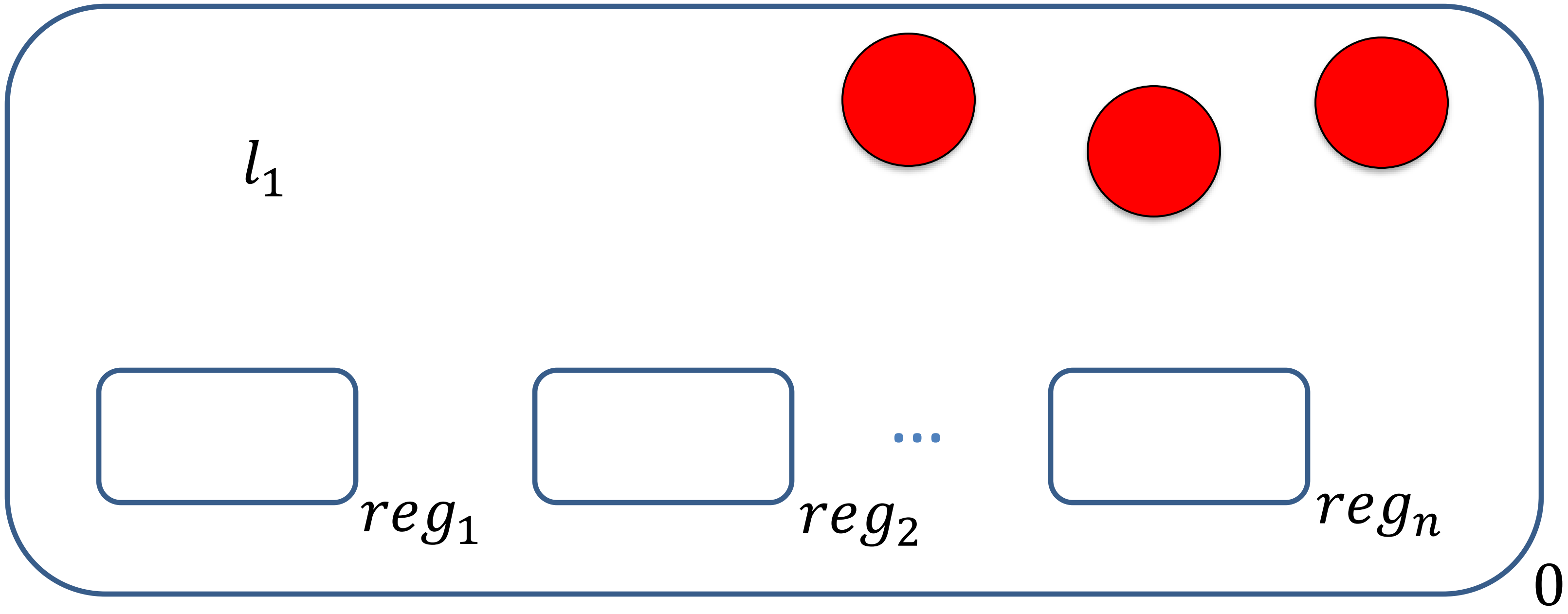
Calculation

$P_{ADD} = \{a\# \to aa\#\}$

Non-deterministic next instruction addressing

$[\,[\,l_1 P_{ADD}\,]_i\,]_0 \to [\,l_2 P_{ADD}\,[\,]_i]_0$

$[\,[\,l_1 P_{ADD}\,]_i\,]_0 \to [\,l_3 P_{ADD}\,[\,]_i]_0$



Work in progress and future research

- Connection with other models: initially consider P colonies
- Self-replicated machines: plasmids inside themselves
- Plasmid evolution: polymorphic rules
- Plasmid mobility: introducing polarizations, nested membranes, …
- Plasmid degradation: allow the dissolution of the plasmid membrane (so, the plasmid rules remain in the host region and the plasmid dissapears)

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Thank you !!

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