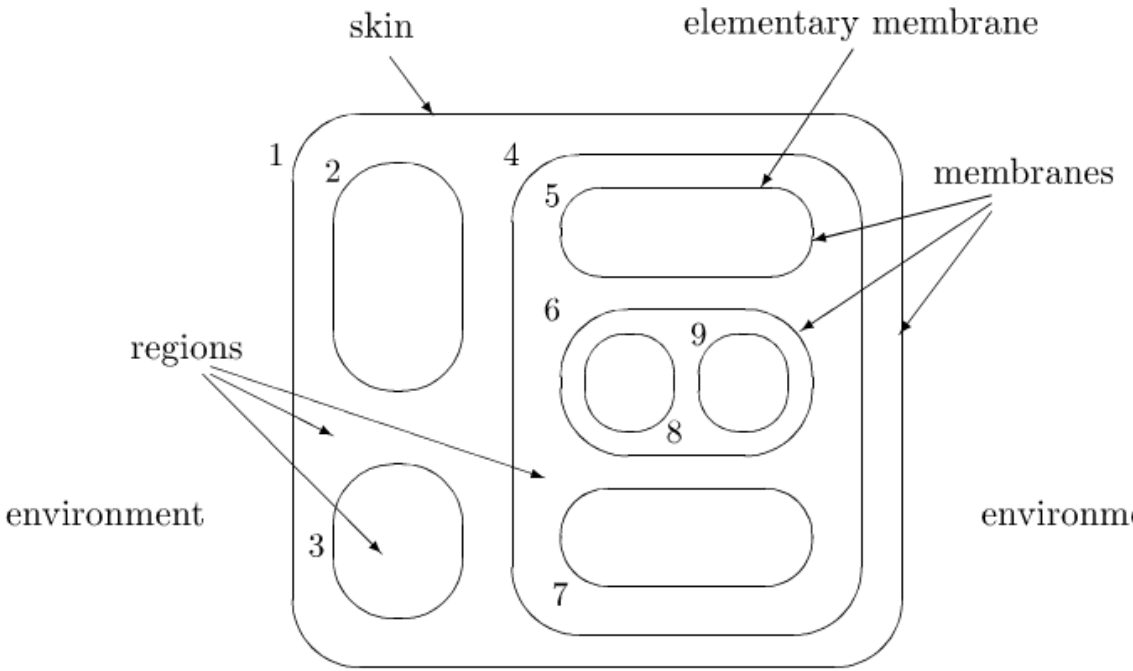
Sequential P Systems with Active Membranes Working on Sets

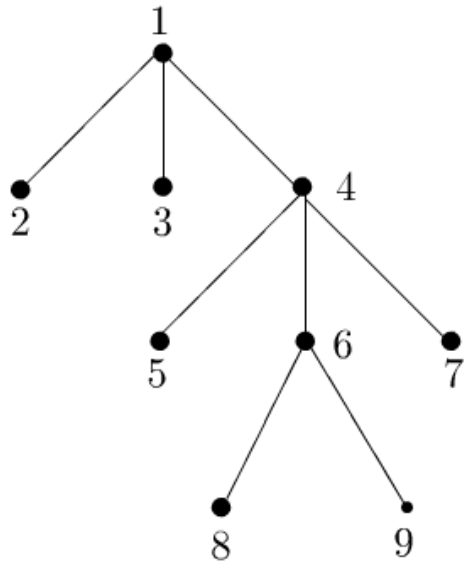
Michal Kováč, Damas Gruska

Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovakia

30.9.2015

Membrane structure





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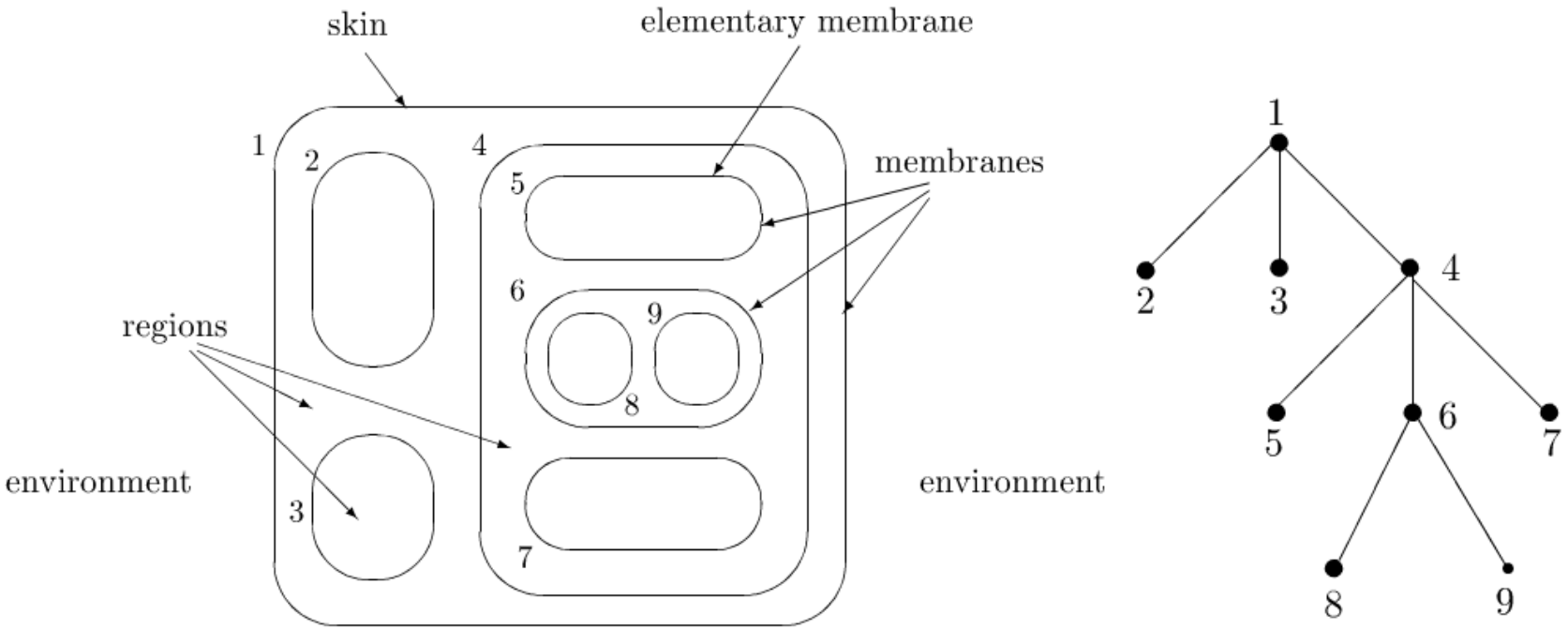

- Multisets

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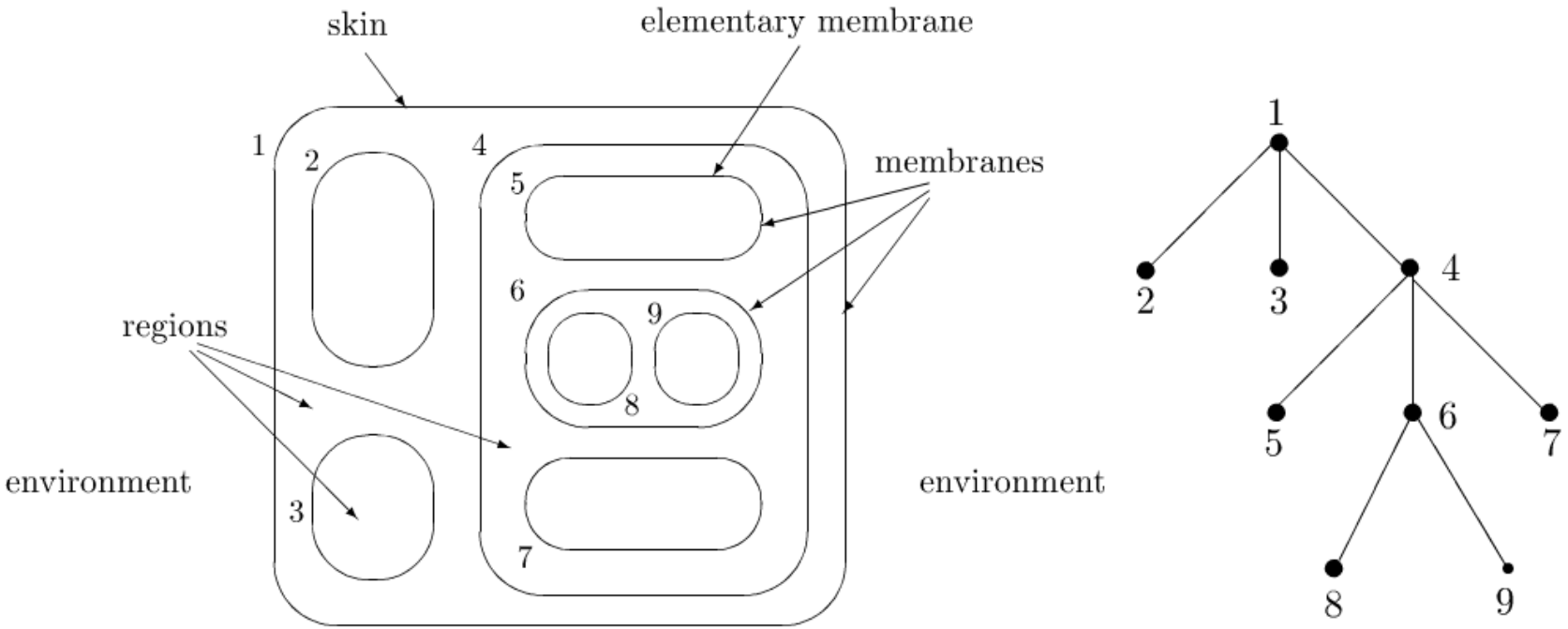

- Multisets
- Rewriting rules

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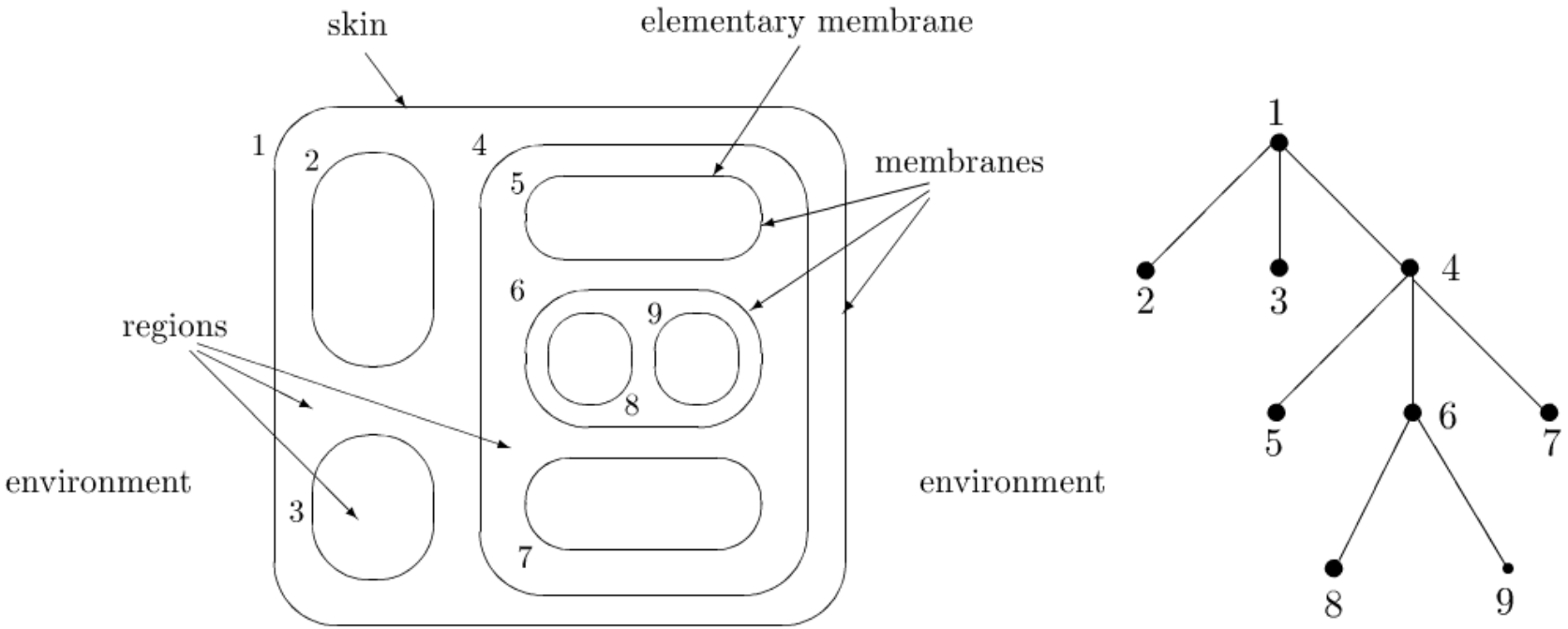

- Multisets
- Rewriting rules
- Passive vs. Active

Computation

- Maximal parallel vs. sequential

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- Language
  - Generating mode: language of sequences of objects sent out from the skin membrane
  - Accepting mode: accept the given configuration if the system can halt

Using sets instead of multisets

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Using sets instead of multisets

- Representing state by a multiset of objects may lead to potential problems in two respects.
  - How realistic is the counting if one needs to represent huge number of molecules?
  - Impractical verification techniques due to the size of state space.

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- Kleijn, Koutny [Kleijn and Koutny, 2011]: "min-enabled" computational step = sequential
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- Properties:
  - No conflict (objects can participate as reactants in as many rules as they want).
  - If an object is used as a reactant for at least one rule, it is consumed.

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  - $c : V(T) \rightarrow 2^{\Sigma}$

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- $C = (T, I, c)$
  - $I : V(T) \to \{0, \ldots, m-1\}$
  - $c : V(T) \to 2^{\Sigma}$
- Rewriting rules
  - $u \to w$
  - $u \to w\delta$
  - $u \to [_j v_1]_j v_2$,
    where $u \subseteq \Sigma, |u| \geq 1$, $v_1, v_2 \subseteq \Sigma$ and $w \subseteq (\Sigma \times \{\cdot, \uparrow, \downarrow_j\})$

Register machine

- Registers with non-negative values $r_1, r_2, \ldots$
- Labeled instructions $i : op$, where op is:
  - $add(j, k)$
  - $sub(j, k, l)$
  - $halt$
- State = (instruction pointer, values of registers)
- Step: modify the register value, move the instruction pointer

Simulation of a register machine

Simulation of a register machine (2 registers, 3 instructions):

- $1 : sub(1, 2, 3)$
- $2 : add(2, 1)$
- $3 : halt$

Example simulation

Skin membrane (6 rules):

- $x_1 \to x_1 \downarrow_1 \quad , \; x_2 \to x_2 \downarrow_2$
- $x_2 t_2 \to [_2 y_1 t_2]_2$
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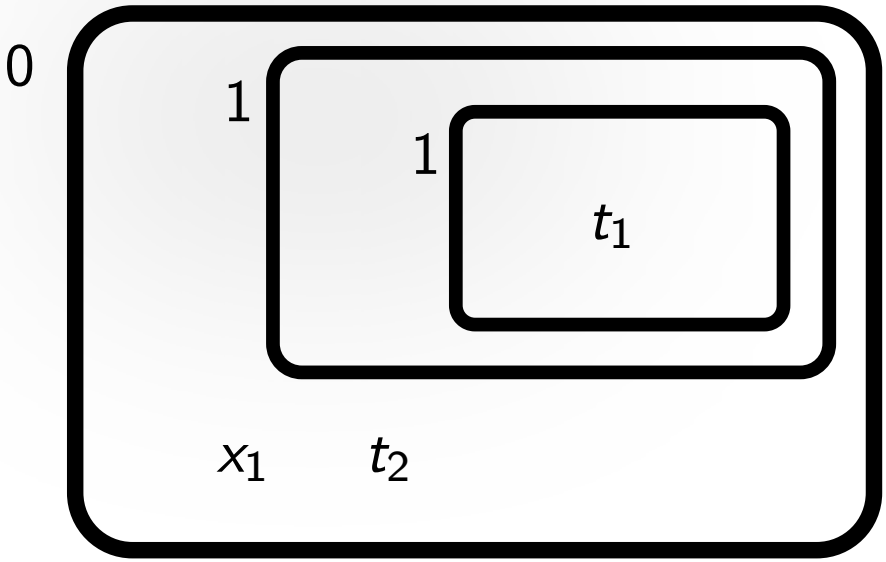

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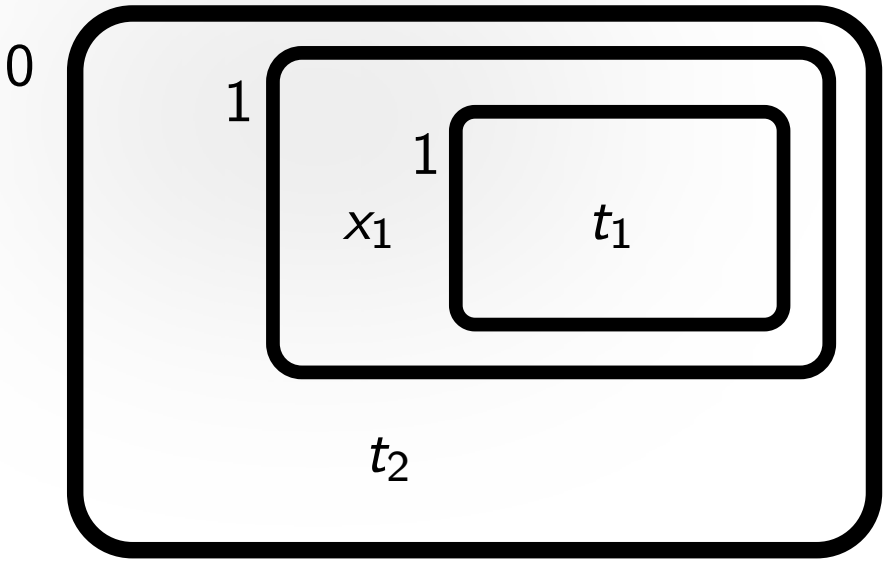

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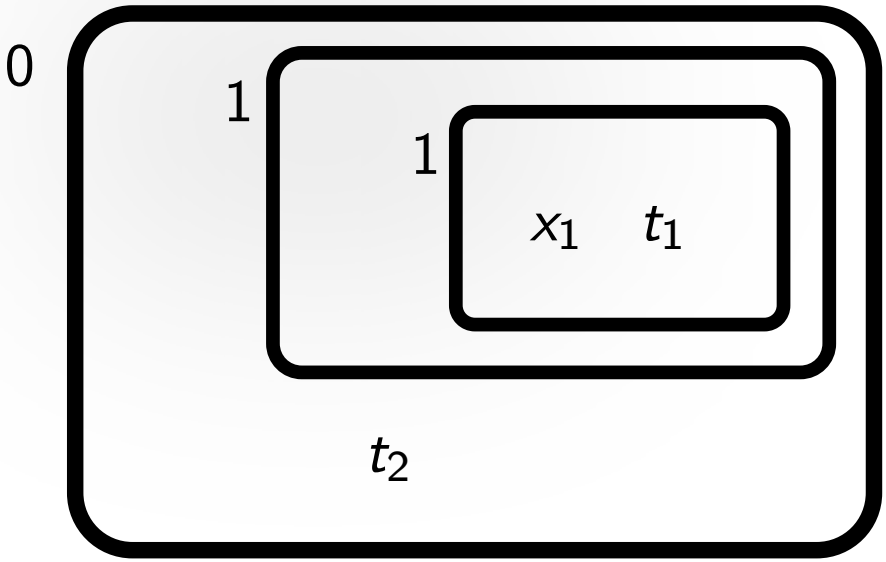

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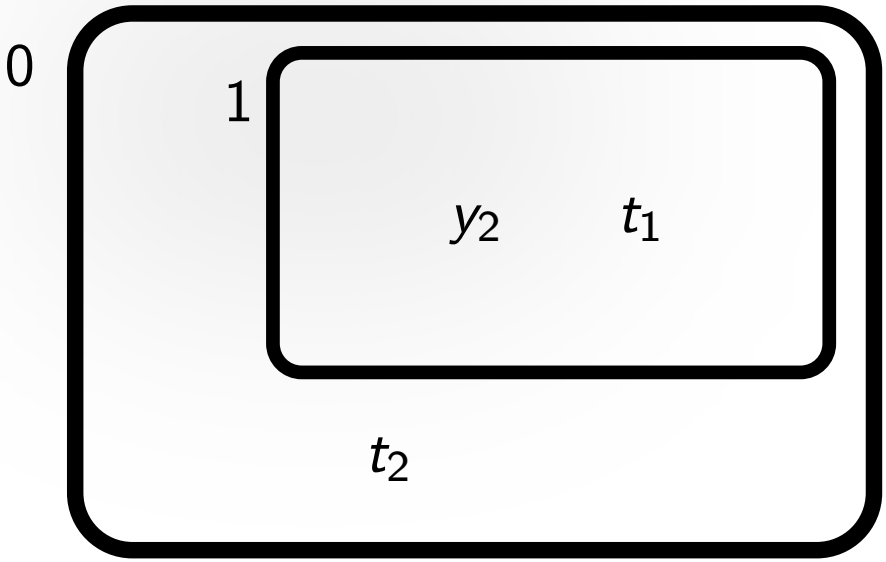

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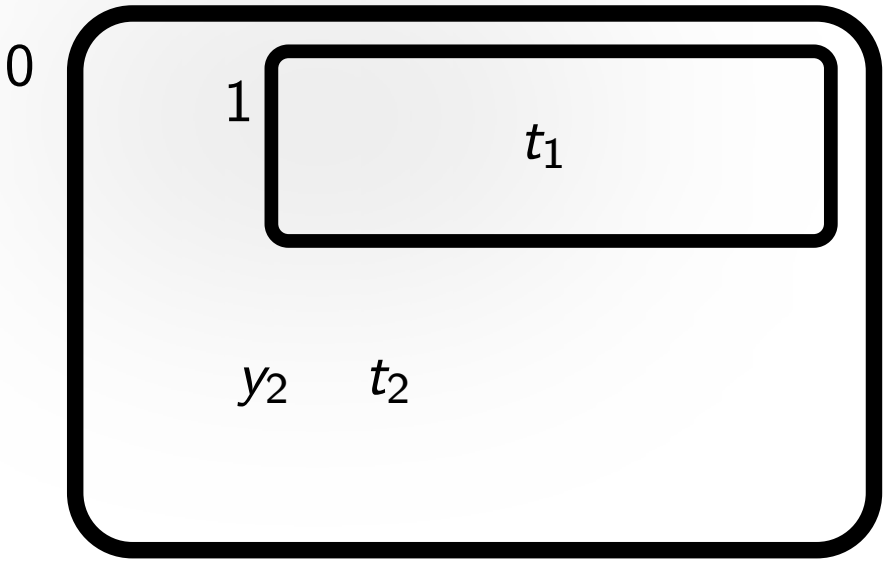

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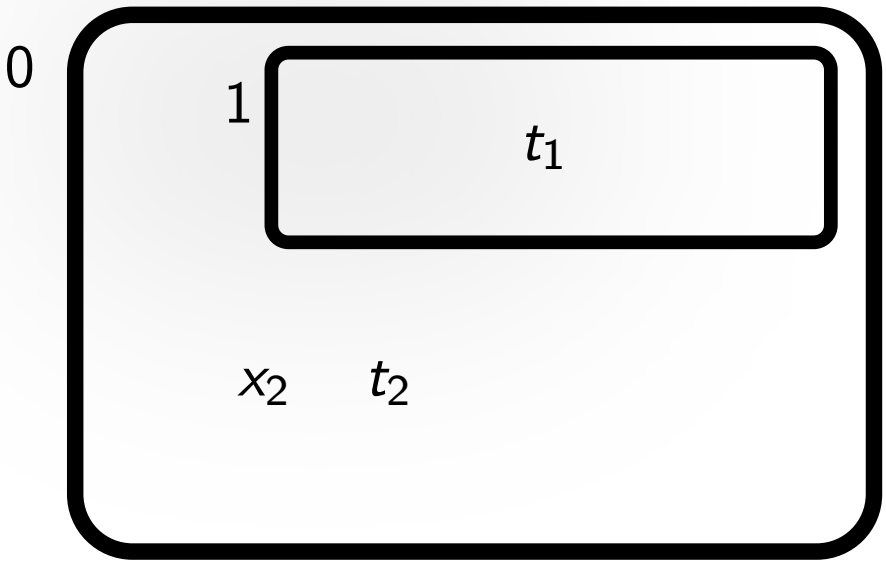

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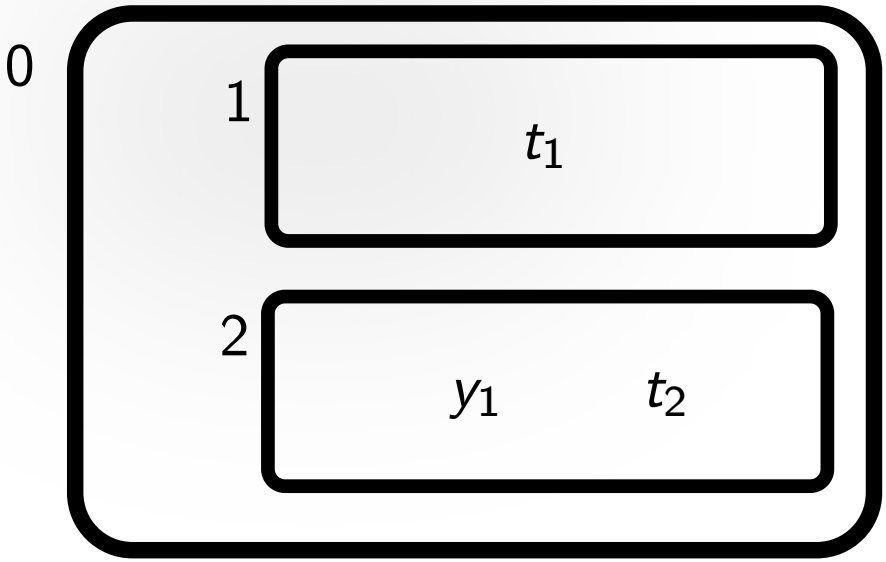

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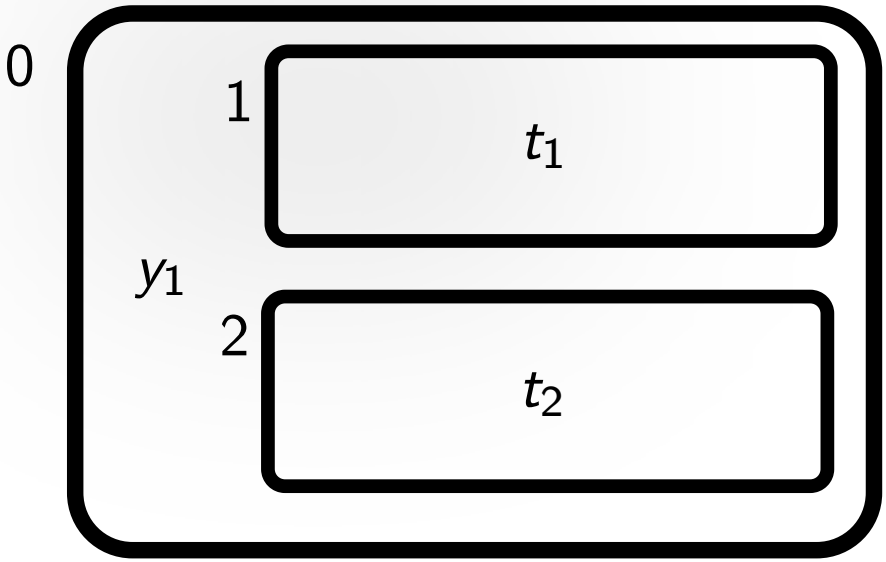

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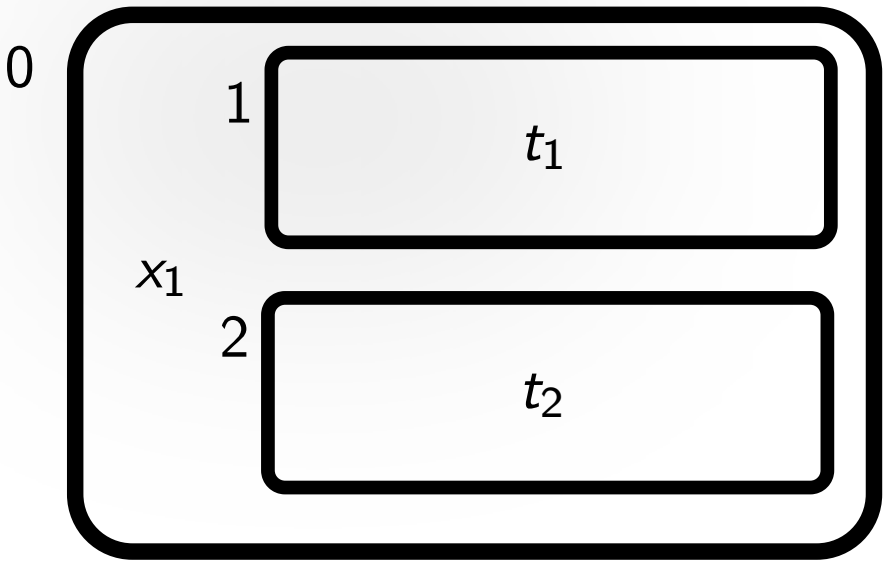

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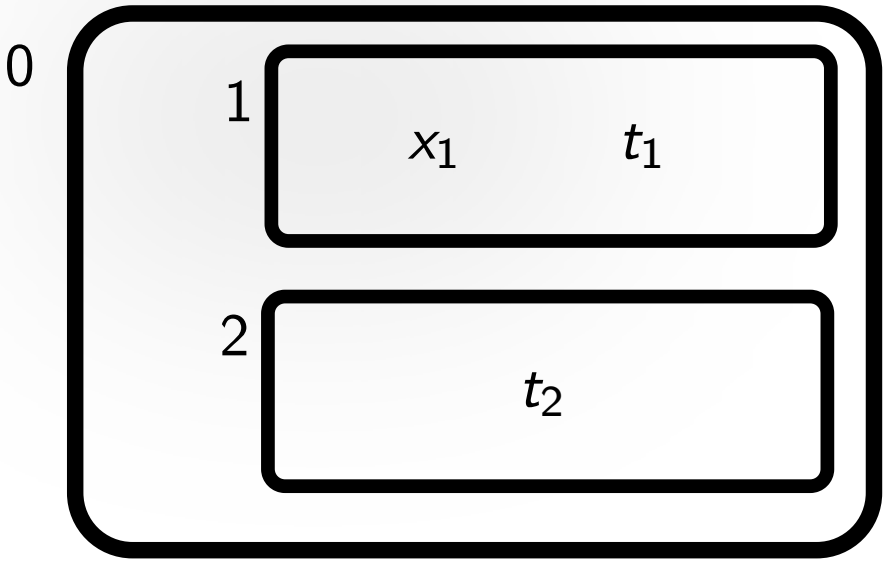

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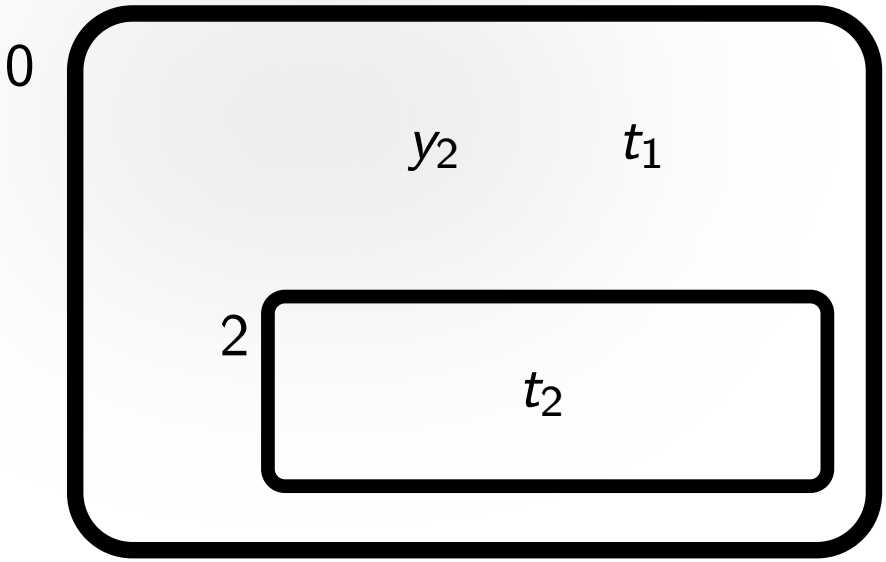

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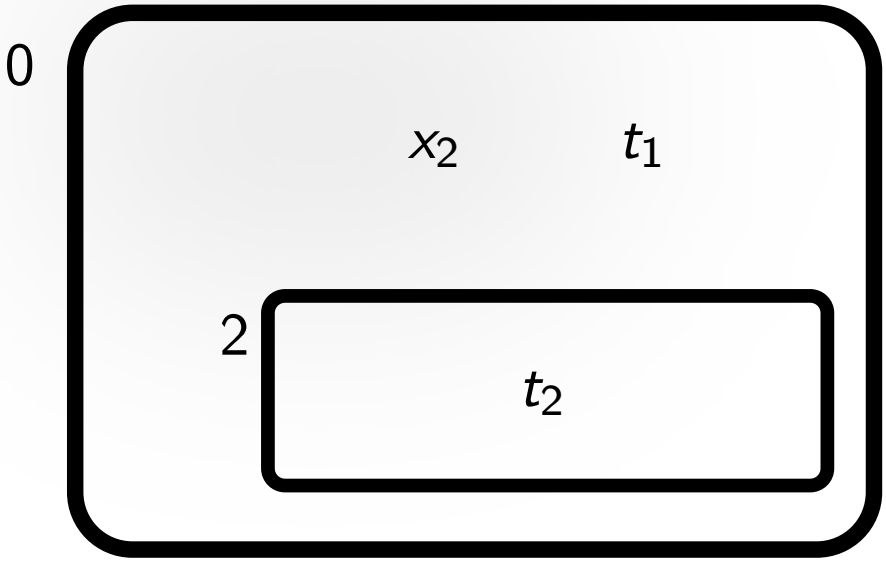

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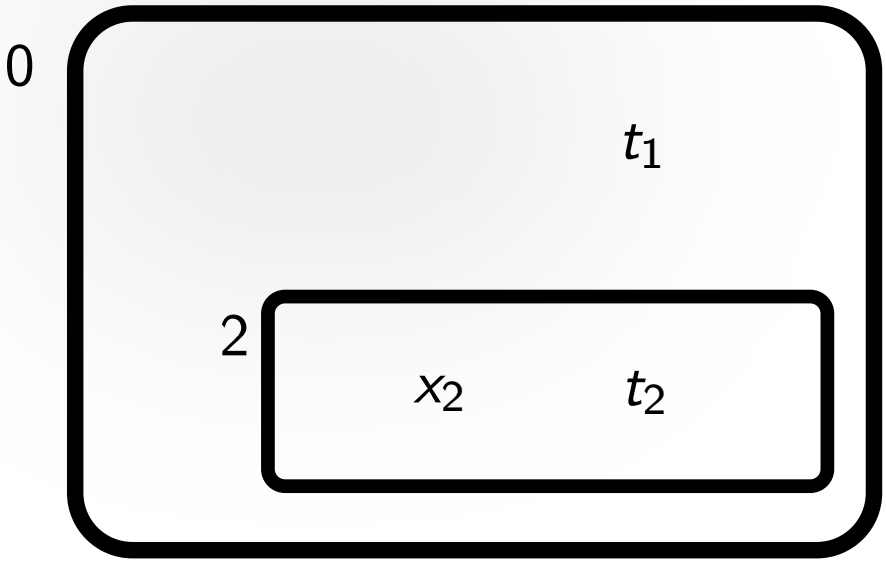

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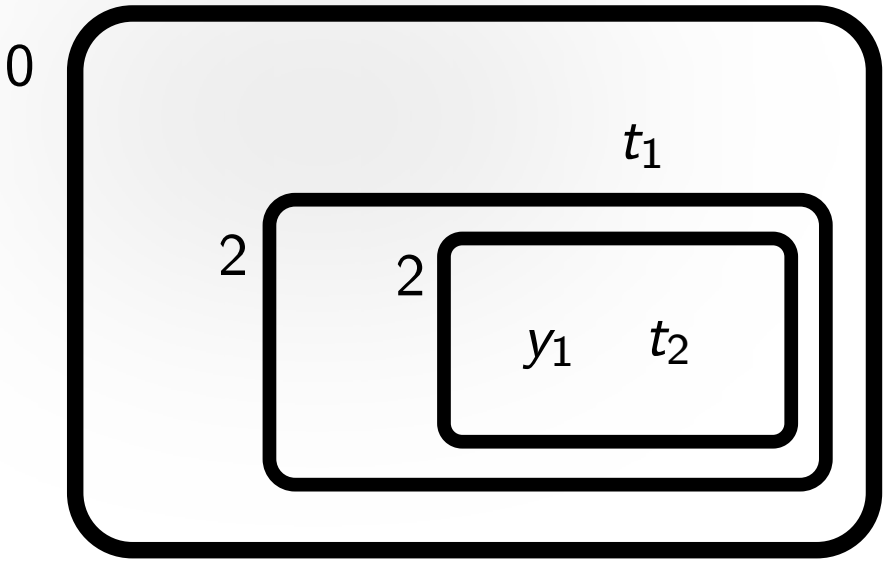

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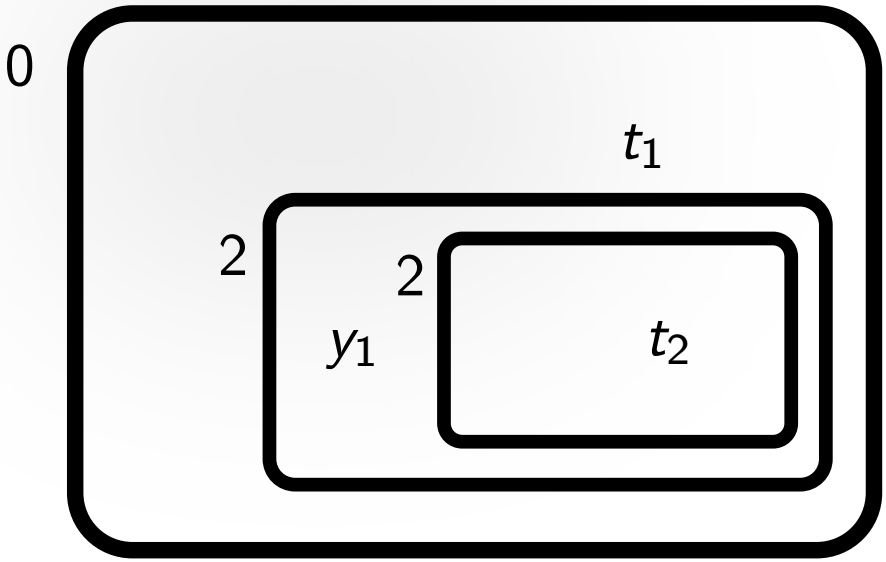

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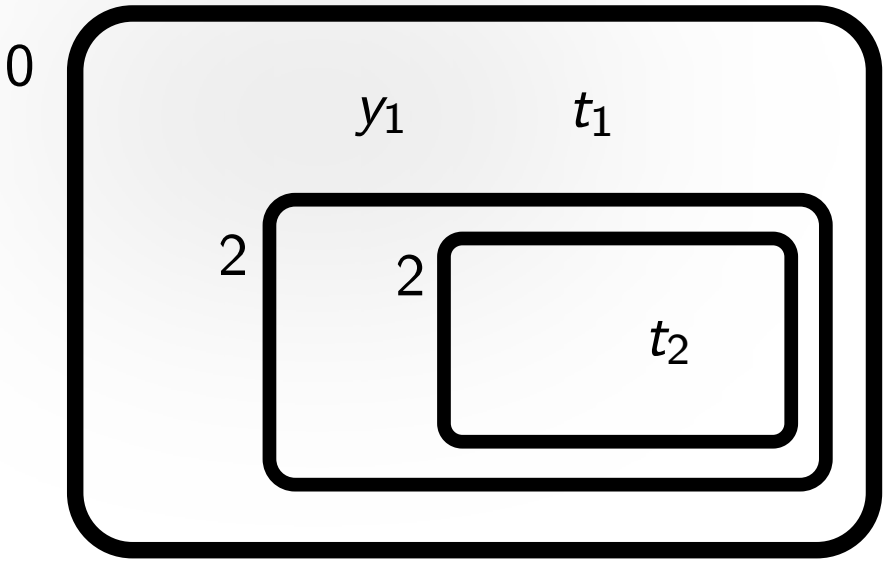
- $x_2 t_2 \to [_2 y_1 t_2]_2$
- $y_1 \to y_1 \uparrow \;\; , \; y_2 \to y_2 \uparrow$

Example simulation

Skin membrane (6 rules):

- $x_1 \rightarrow x_1 \downarrow_1 \ , \ x_2 \rightarrow x_2 \downarrow_2$
- $x_2 t_2 \rightarrow [_2 y_1 t_2]_2$
- $x_1 t_1 \rightarrow x_3$
- $y_1 \rightarrow x_1 \ , \ y_2 \rightarrow x_2$



Membrane 1 (4 rules):

- $x_1 \rightarrow x_1 \downarrow_1$
- $x_1 t_1 \rightarrow y_2 t_1 \delta$
- $y_1 \rightarrow y_1 \uparrow, \ y_2 \rightarrow y_2 \uparrow$

Membrane 2 (4 rules):

- $x_2 \rightarrow x_2 \downarrow_2$
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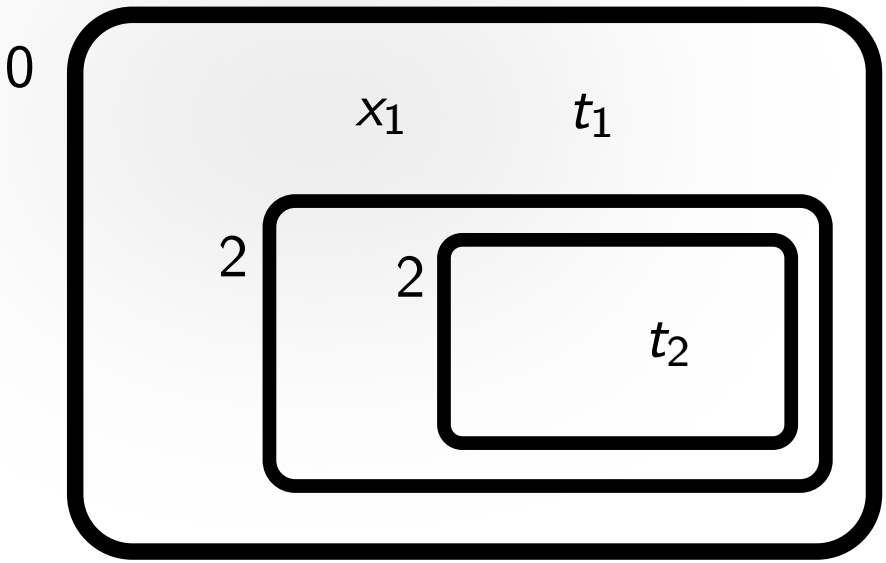
- $y_1 \to x_1 \;\; , \; y_2 \to x_2$



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- $x_1 t_1 \to x_3$
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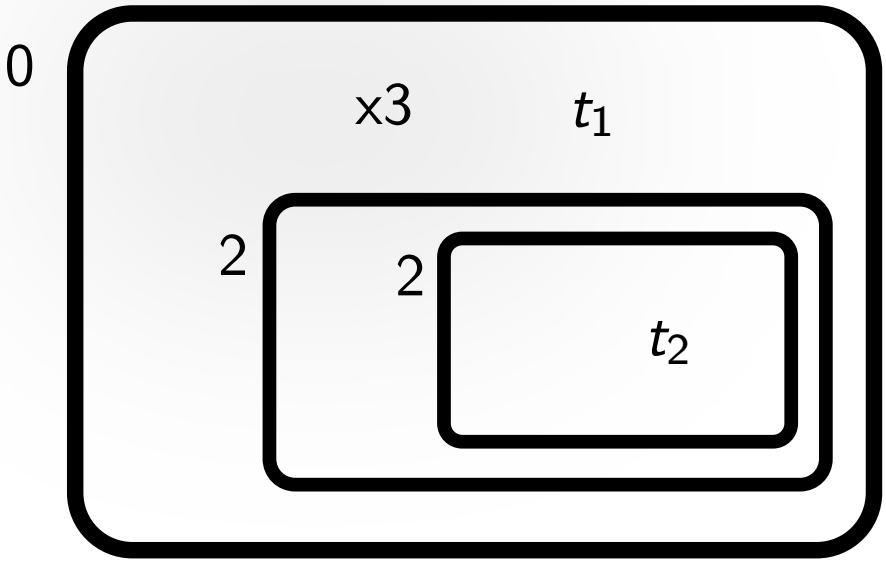

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Membrane 2 (4 rules):

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- $x_2 t_2 \to [_2 y_1 t_2]_2$
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Issues with original semantics

- Two issues:
  1. Explicit membrane creation rule

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- Alternatives:
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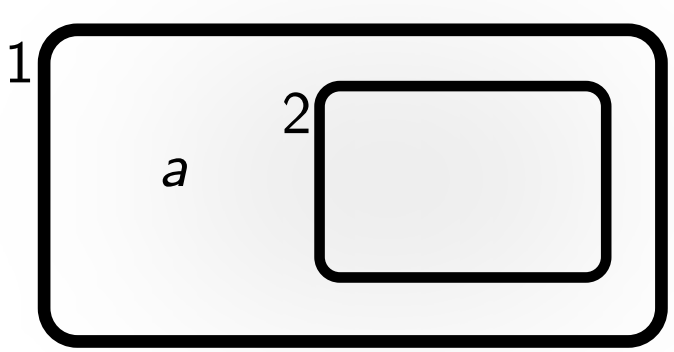
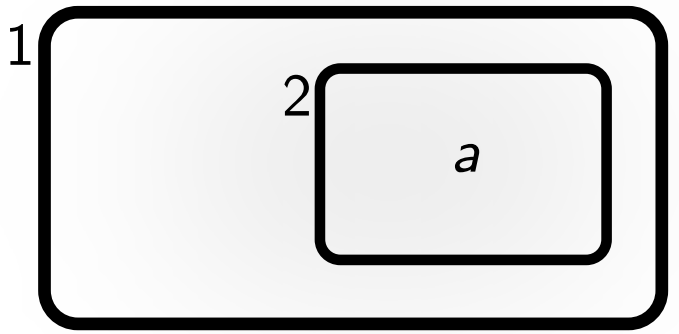
  2. Wrap-or-create

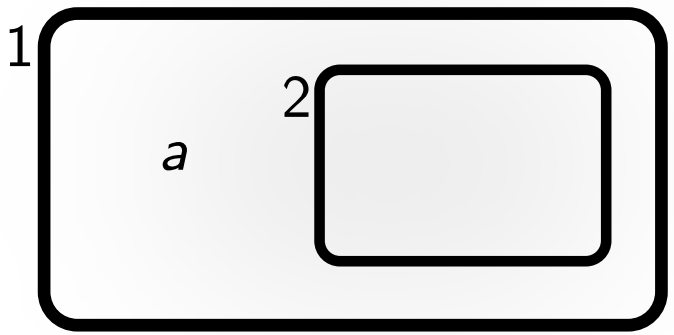
Inject-or-create semantics



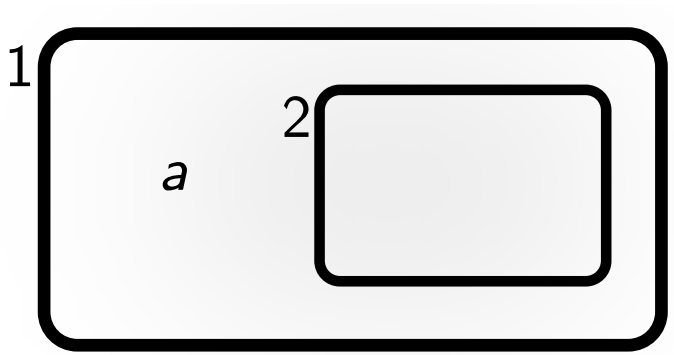
Inject-or-create semantics

$$a \rightarrow a \downarrow_2$$

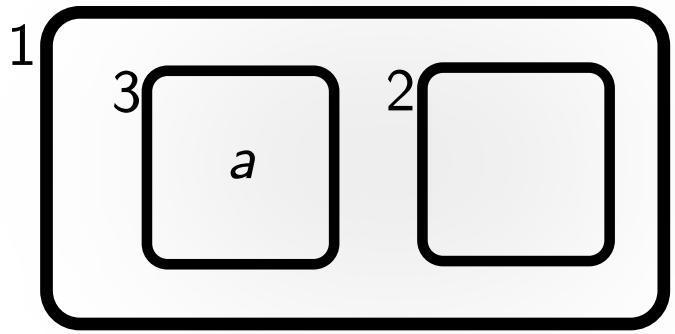




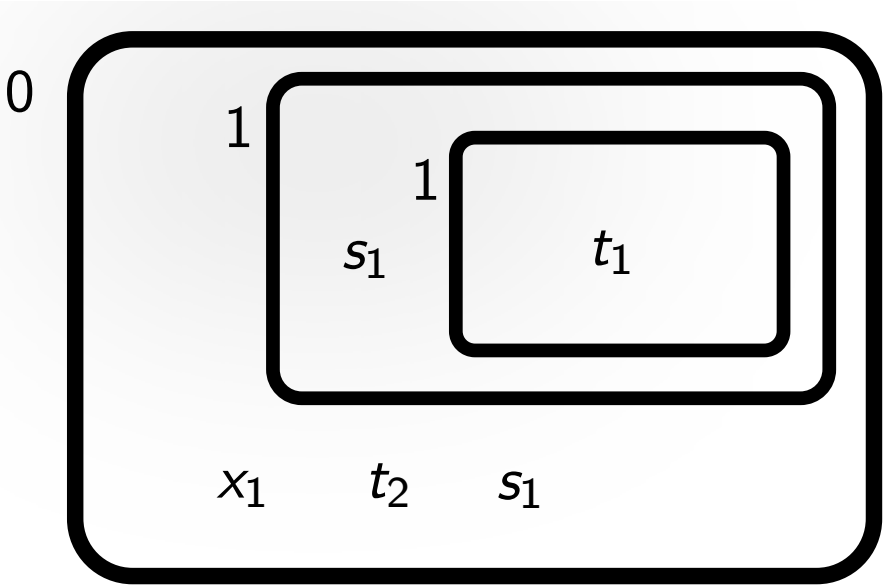
Inject-or-create semantics



$a \rightarrow a \downarrow_3$



Wrap-or-create semantics



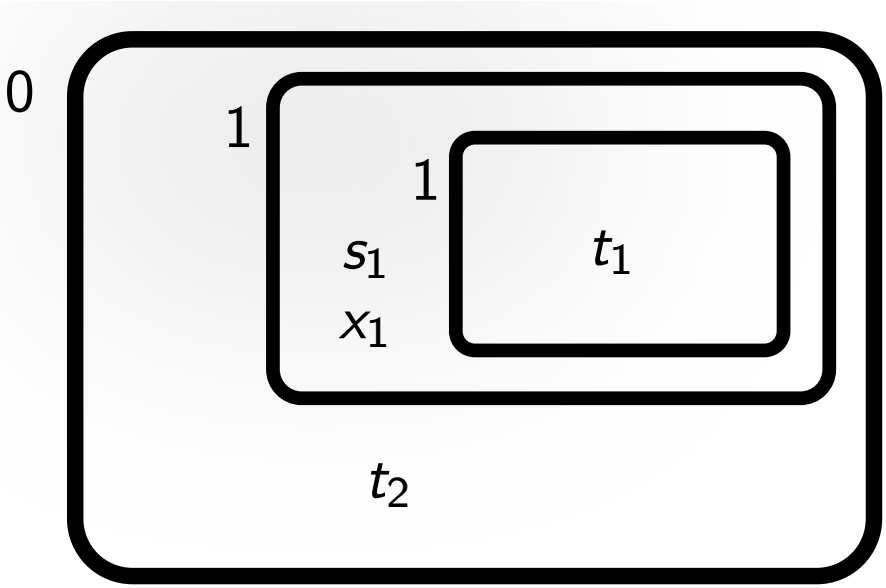
Skin membrane:

- $x_1 t_1 \rightarrow x_3 t_1$
- $x_1 s_1 \rightarrow x_1 \downarrow_1$
- $x_2 s_2 \rightarrow [_2 s_2]_2 s_2 x_1$
- $x_2 t_2 \rightarrow [_2 t_2]_2 s_2 x_1$

Membrane 1:

- $x_1 \rightarrow x_2 \delta$

Wrap-or-create semantics



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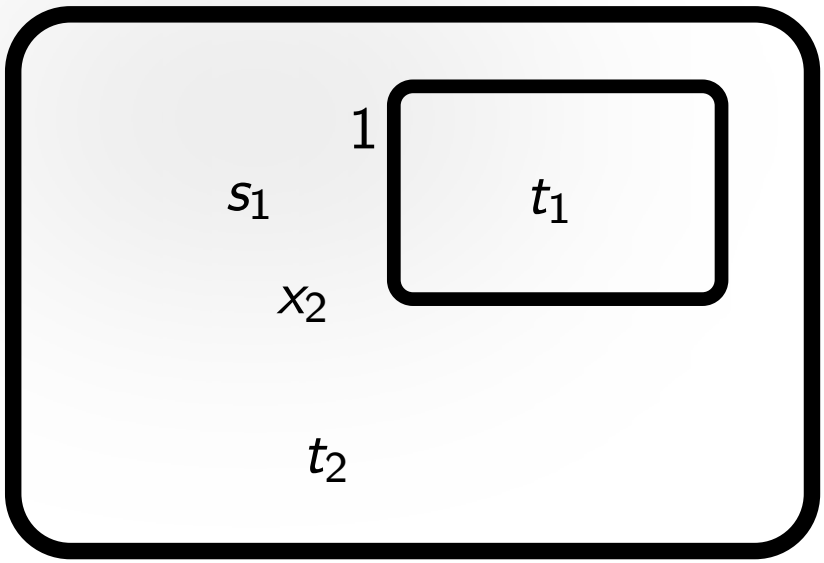

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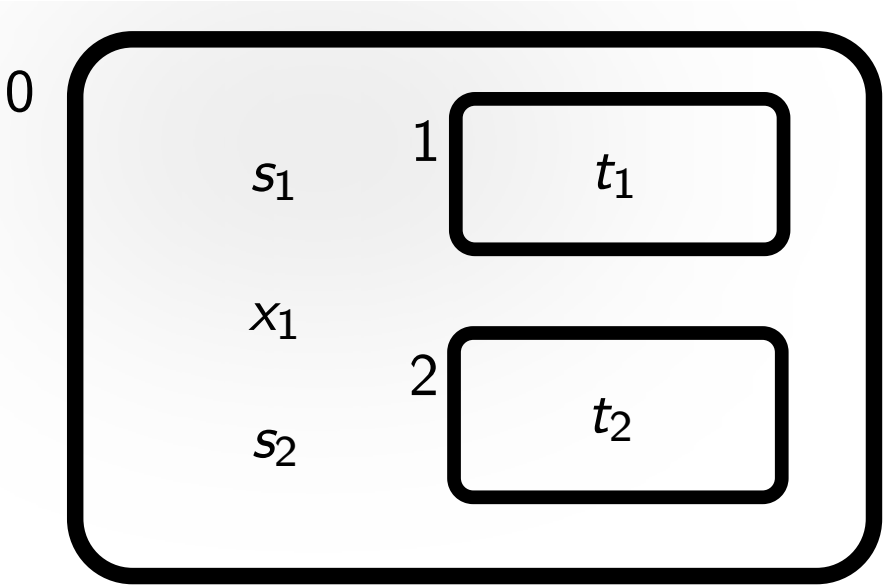

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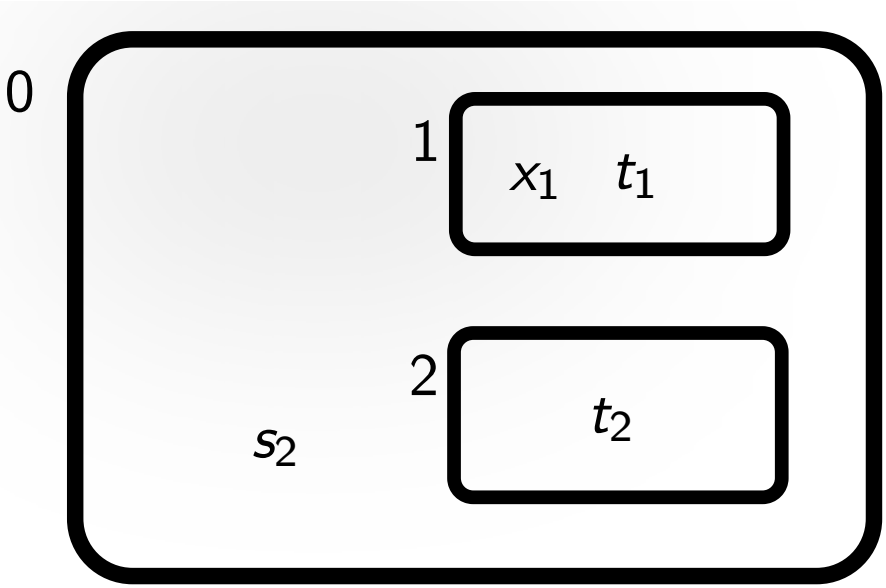

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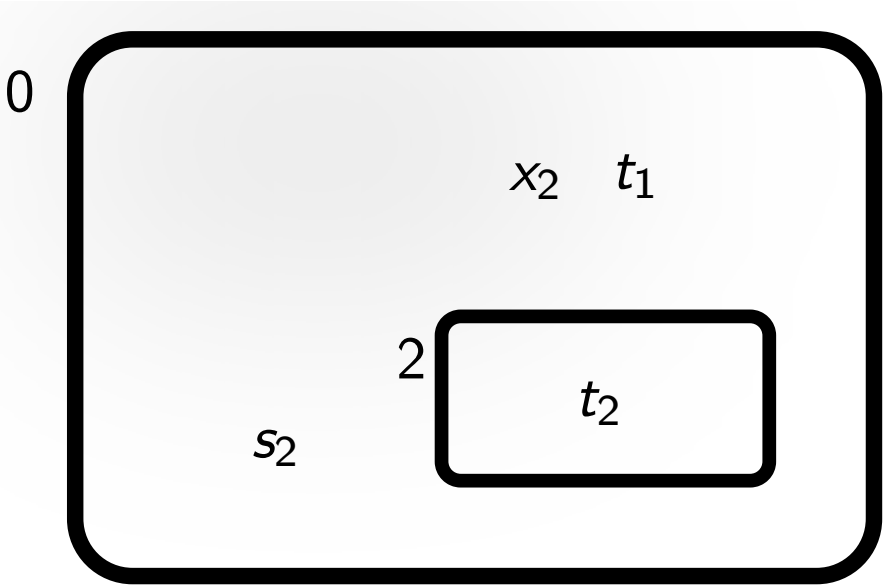

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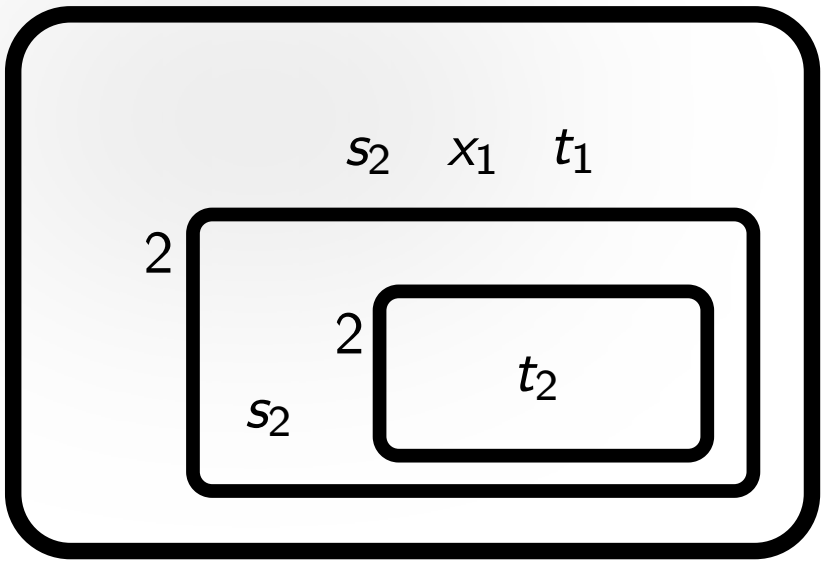

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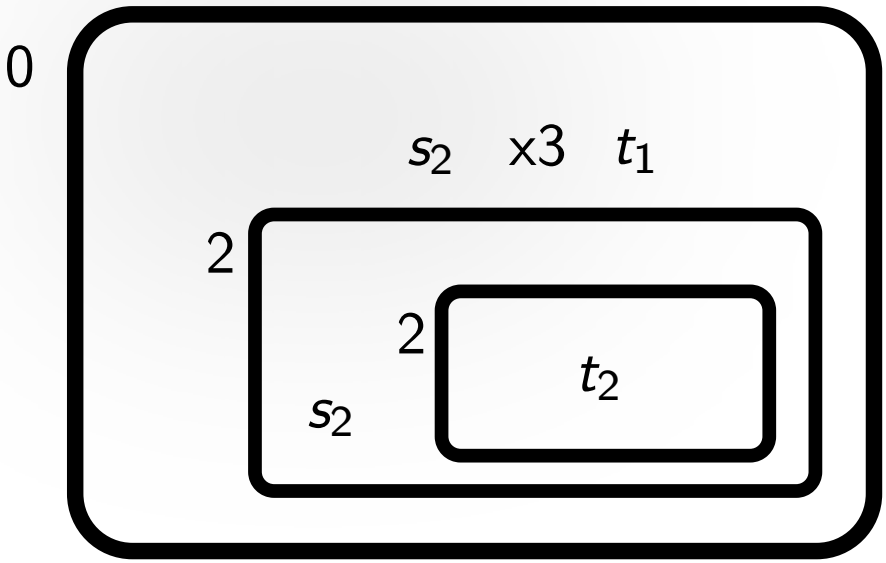

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Comparison of membrane creation semantics

semantics	membranes	time	alphabet
original	$O(n)$	$O(n)$	$2 * \#instr. + \#reg.$
original	$O(log(n))$	$O(log(n))$	$3 * \#instr. + 5$
inject-or-create	$O(log(n))$	$O(log(n))$	$3 * \#instr. + 5$
wrap-or-create	$O(n)$	$O(1)$	$\#instr. + 2 * \#reg.$


Alhazov, A. (2006).
P systems without multiplicities of symbol-objects.
Information Processing Letters, 100(3):124–129.


Kleijn, J. and Koutny, M. (2011).
Membrane systems with qualitative evolution rules.
Fundam. Inf., 110(1-4):217–230.

Thanks for your attention!