Module 13
gro: Specification and Simulation Language for Multicellular Behaviors

CSE 590: Molecular programming and neural computation

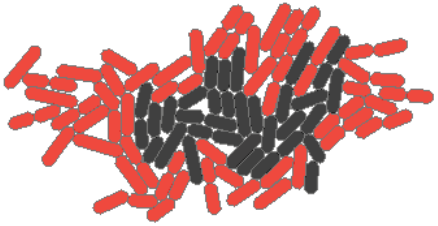
Guest Lecture: Kevin Oishi

Last week…
FSMs for Cellular Information Processing

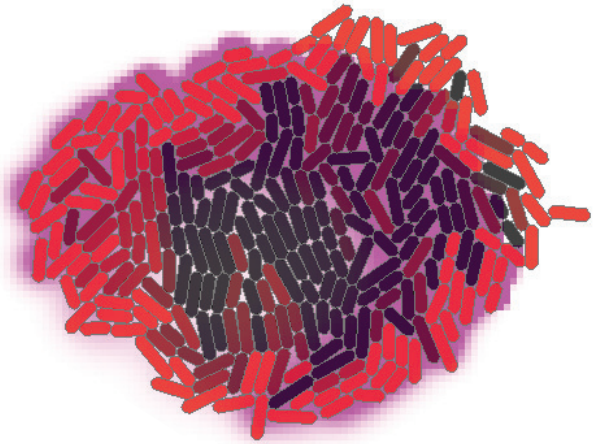
$t = 0$

$t = 45.4$

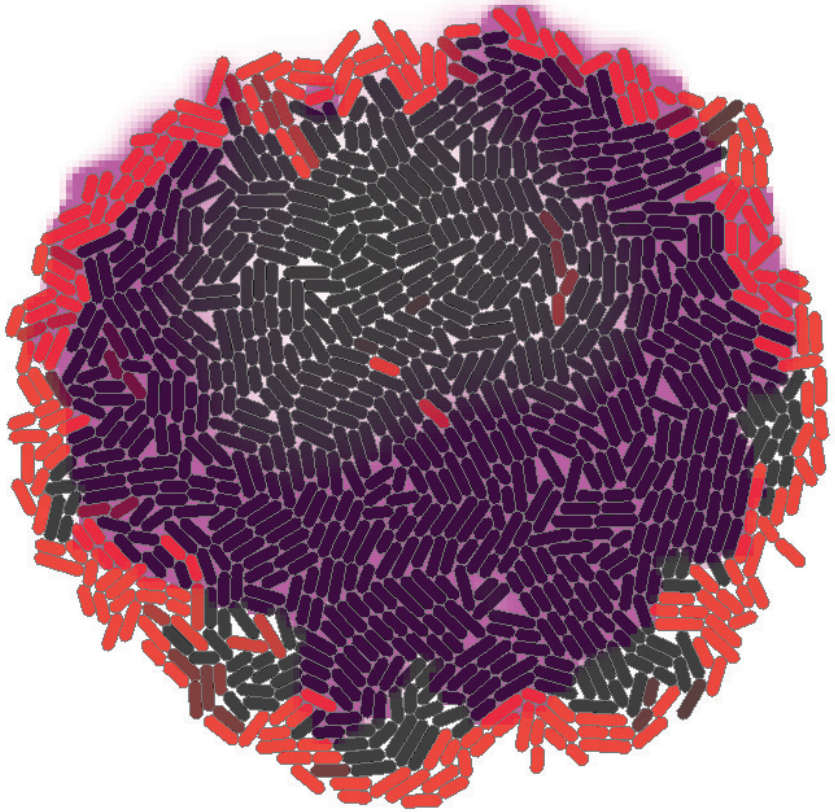
$t = 84.6$



$t = 144.9$



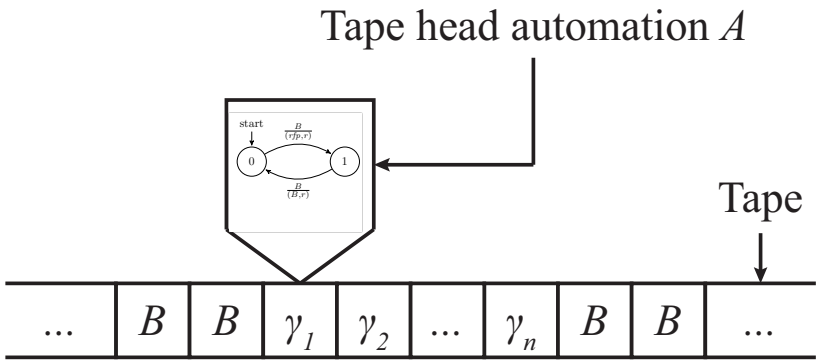
$t = 177.2$

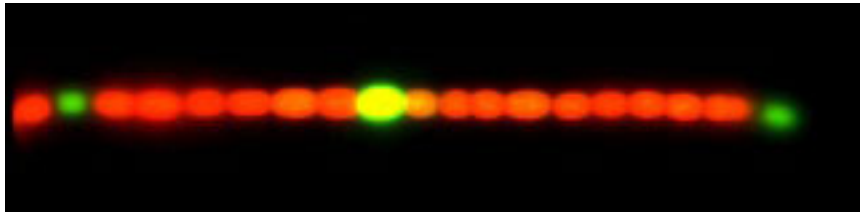


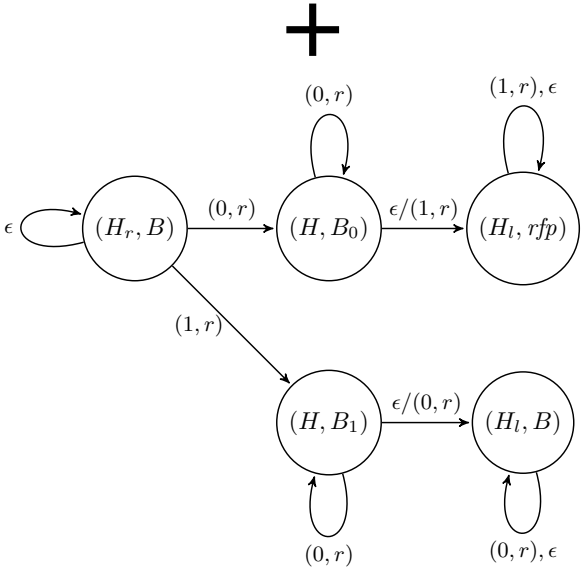
$t = 211.7$

Example: Microcolony Edge Detection FSM Specification

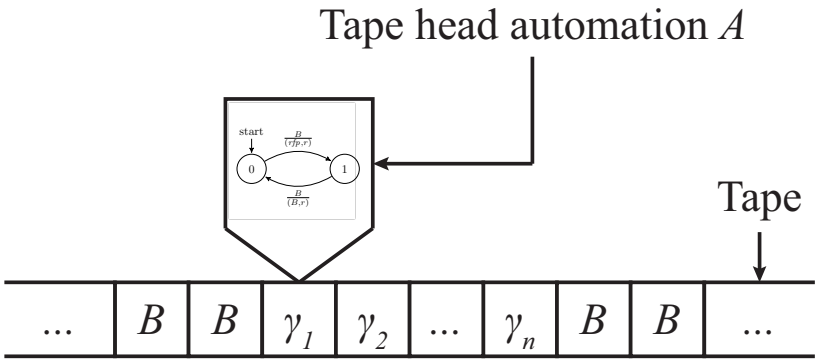
Streptobacillus Turing Tape Machine







Tape Machine

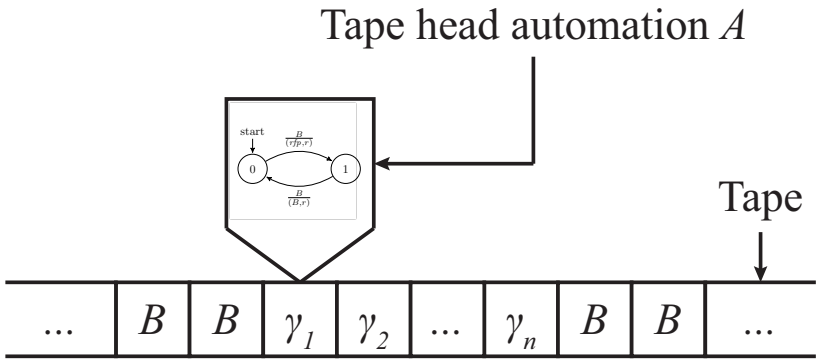


At each time step:

1. Read input symbol from the tape
2. Update state of the automation
3. Write a tape symbol.
4. Move the tape left or right.

Symbol	Meaning
Q	Set of tape head automation states
$\Sigma \subset \Gamma$	Set of input symbols (to the tape machine)
Γ	Set of tape symbols
$\delta : Q \times \Gamma \to Q \times \Gamma \times \{l, r\}$	State transition function
q_0	Initial state of the automation
$B \in \Gamma$	Blank tape symbol symbol
$F \subseteq \Gamma$	Final accepting states

Tape Machine



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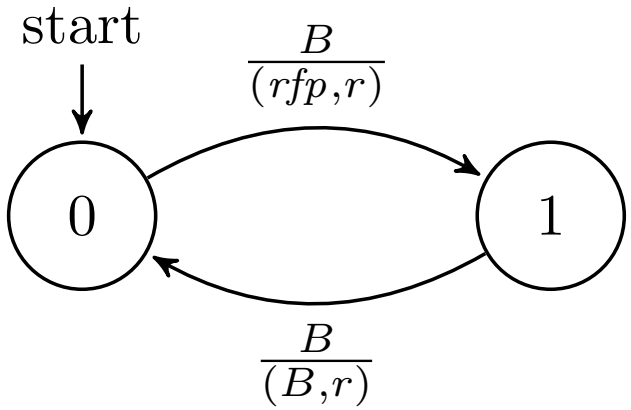

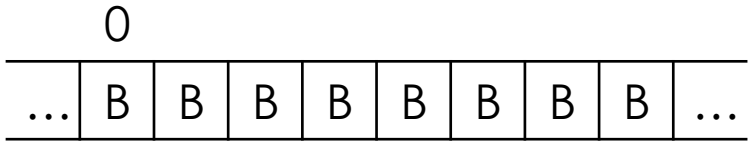

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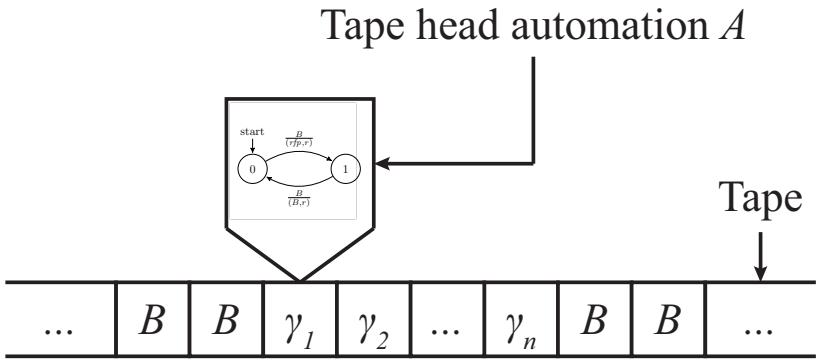

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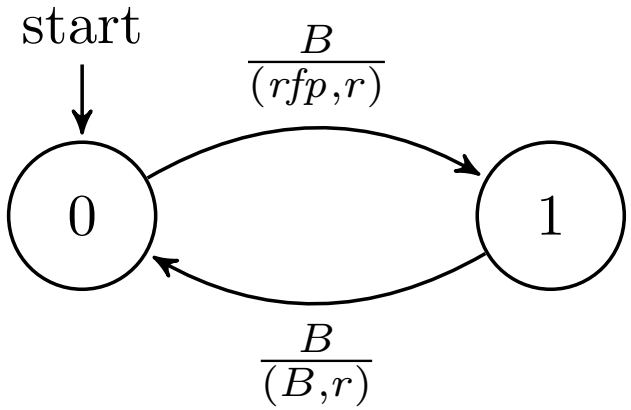

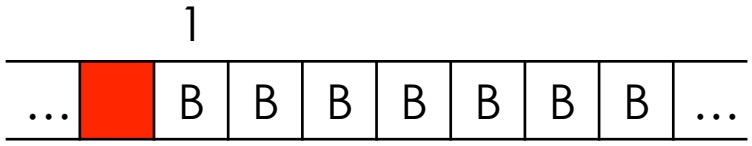

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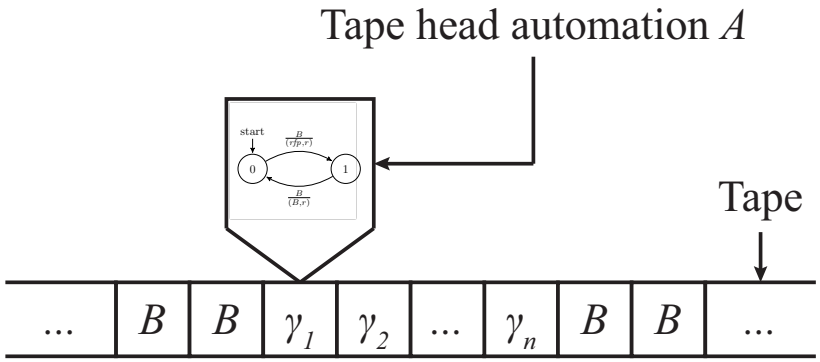

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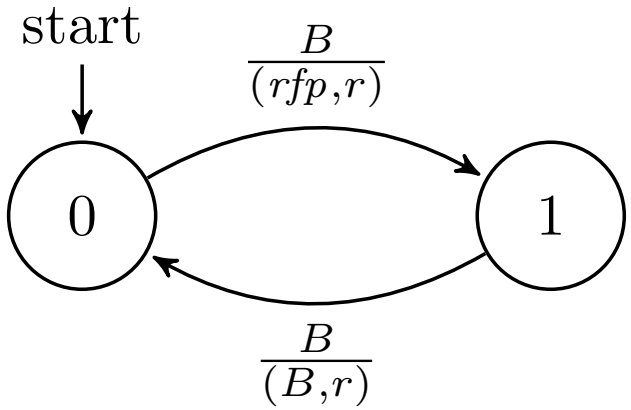

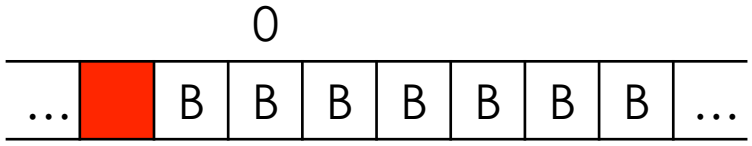

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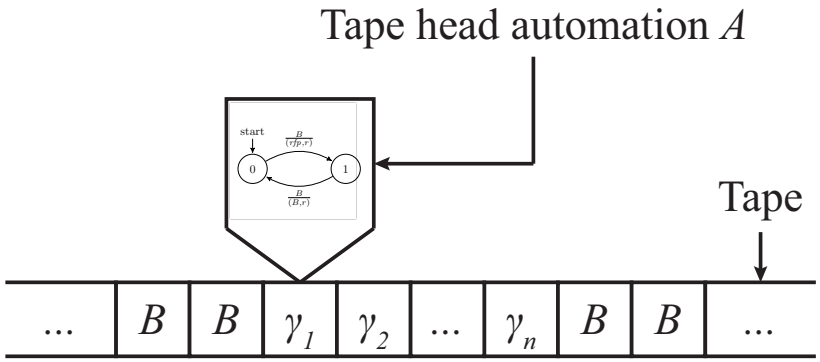

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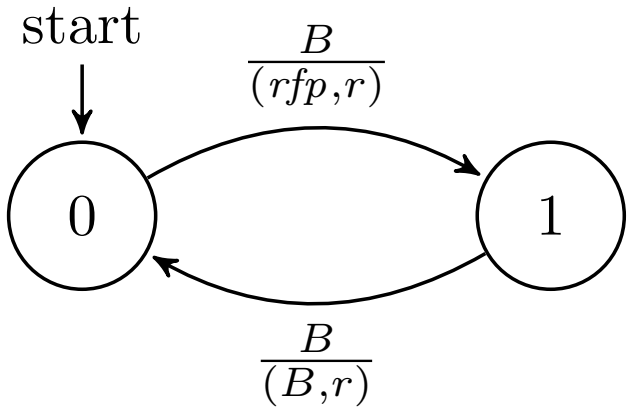

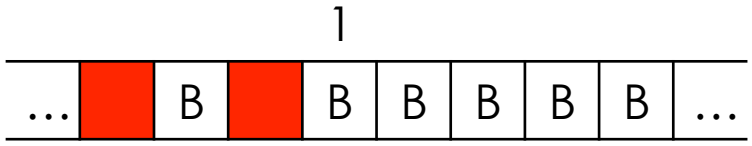

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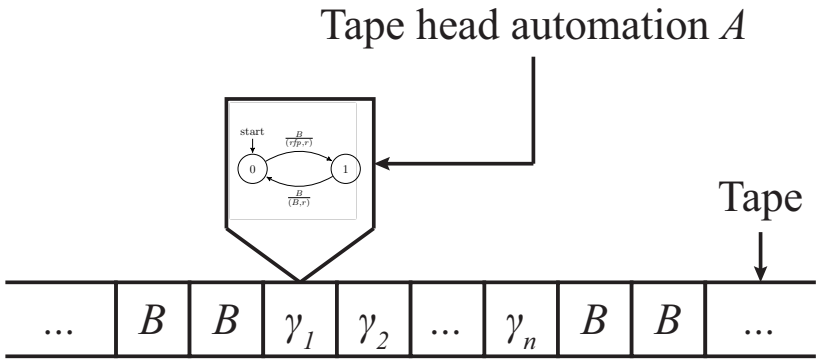

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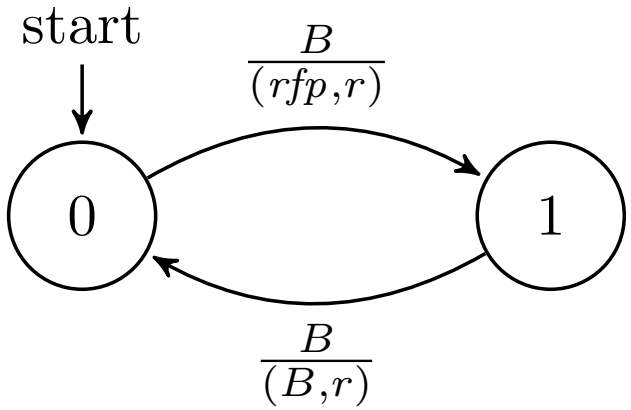

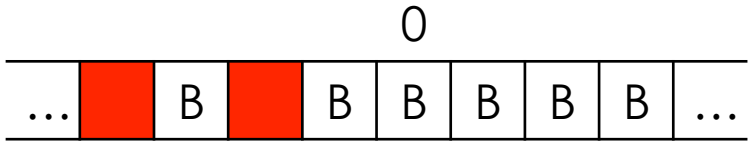

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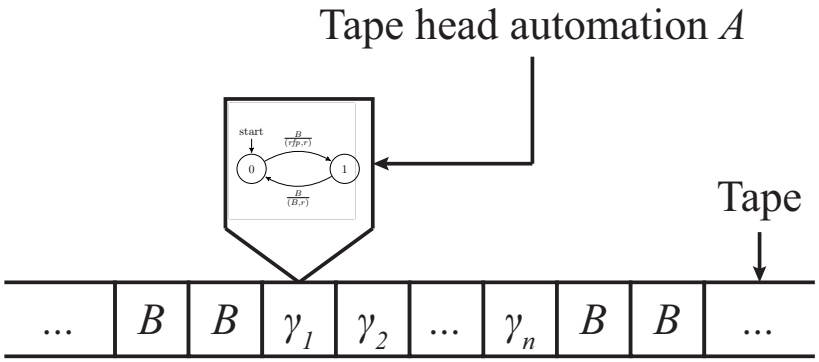

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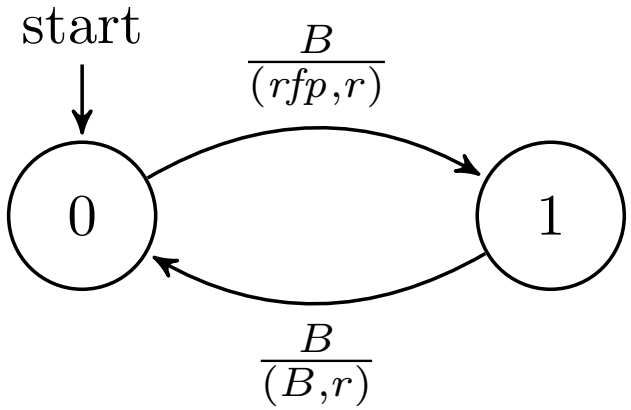

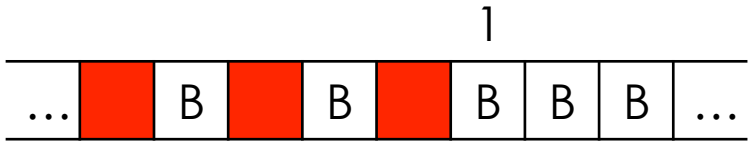

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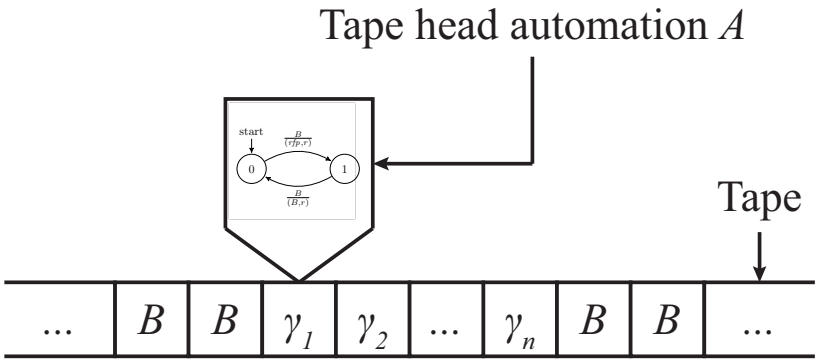

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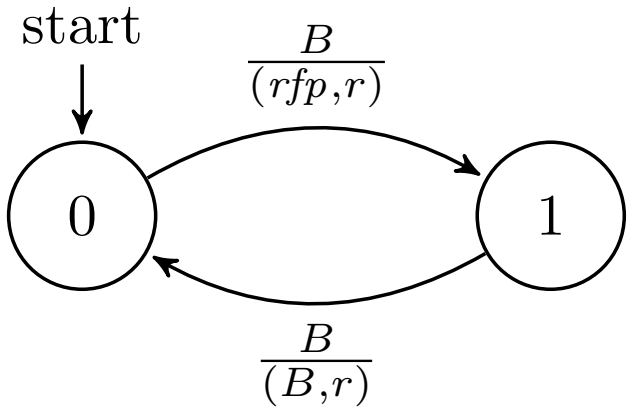

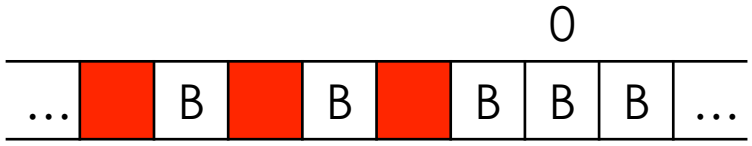

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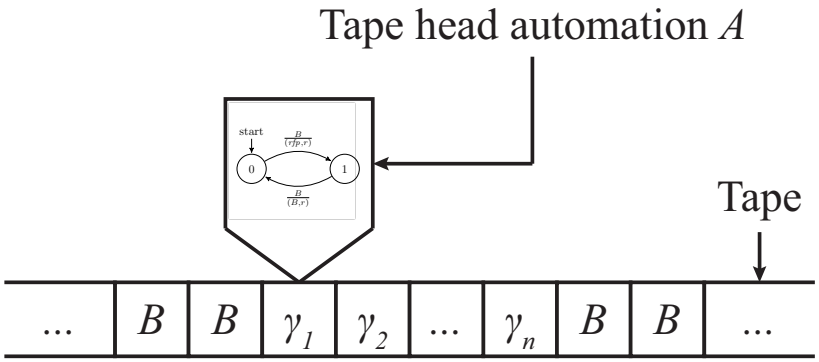

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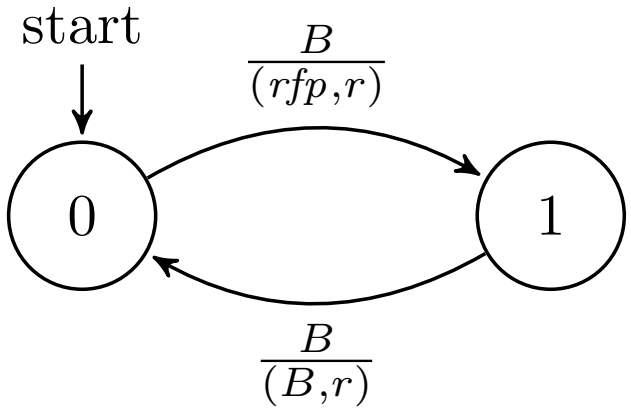
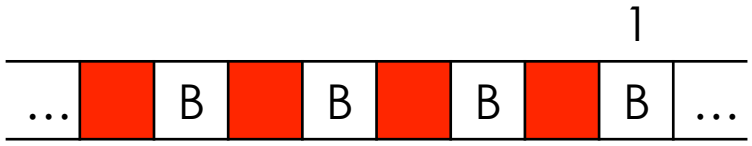
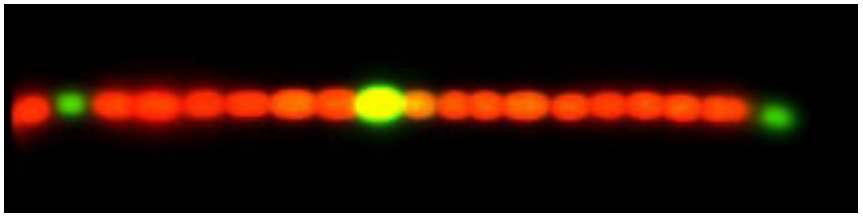




The Tape is a Line of Cells



Basic idea:

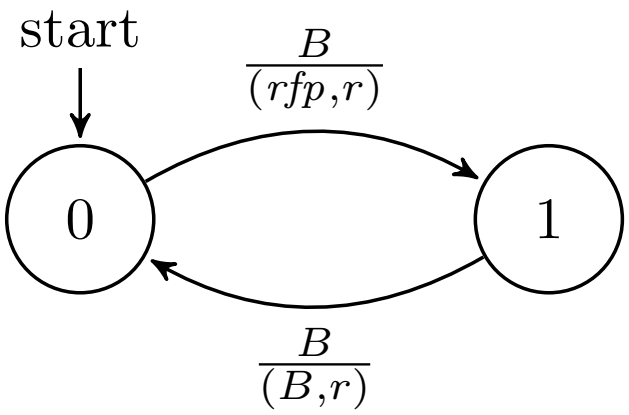
Let $\Theta = \{H, H_l, H_r\}$ denote the position of the tape head (center, left, or right respectively). Define a new automation $A' = (Q', \Sigma, \delta', q_0', F')$ where,

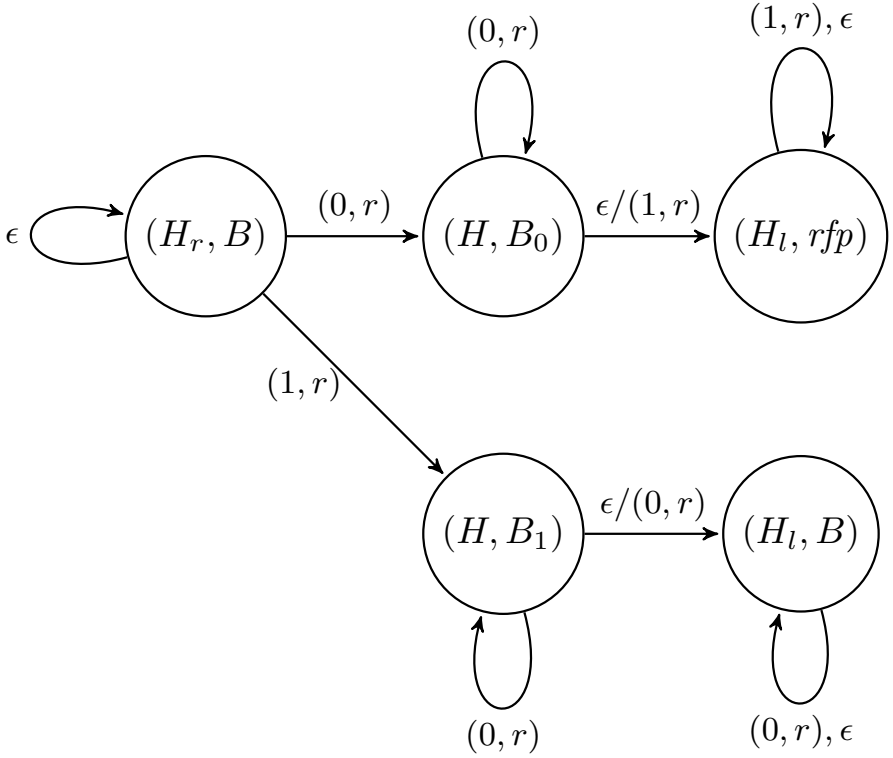
$$\begin{aligned} Q' &= \Theta \times \Gamma \times Q \\ \Sigma &= (Q \times \Gamma) \cup \{\epsilon\} \\ \delta' &= Q' \times \Sigma \to Q' \times \Sigma \\ q_0' &\in Q' \\ F' &\subseteq Q'. \end{aligned}$$

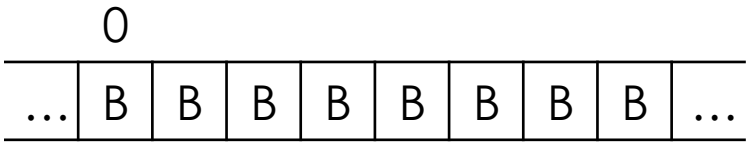
At each time step,

1. The cell holding the "tape head" state *H* updates its state according to the state of the tape.
2. On the state transition, the cell holding the "tape head" state broadcasts the new state of the tape head automation and whether the tape moves left or right relative to the tape head to its immediate neighbors through a small diffusing molecule.

Example: Stripe Formation







	H_l	H	H_r	H_r	H_r	H_r	H_r	H_r	H_r	…
…	B	B_0	B	B	B	B	B	B	B	…

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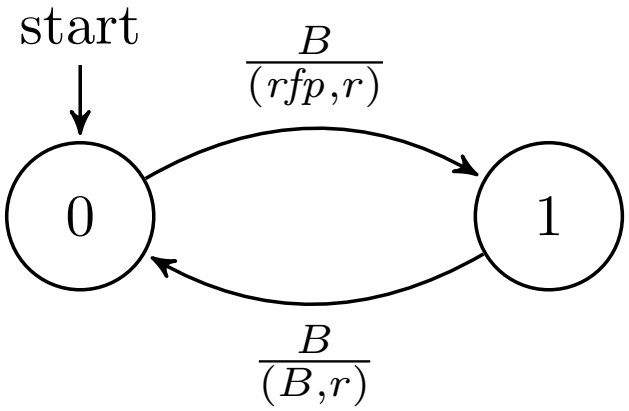

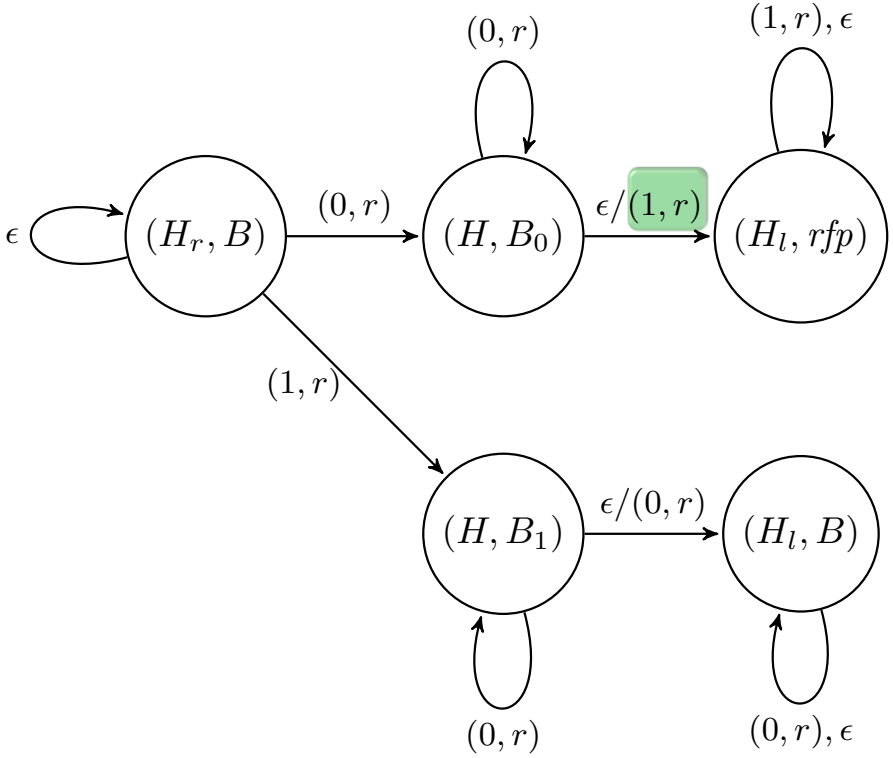

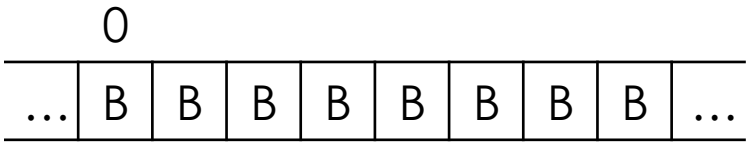

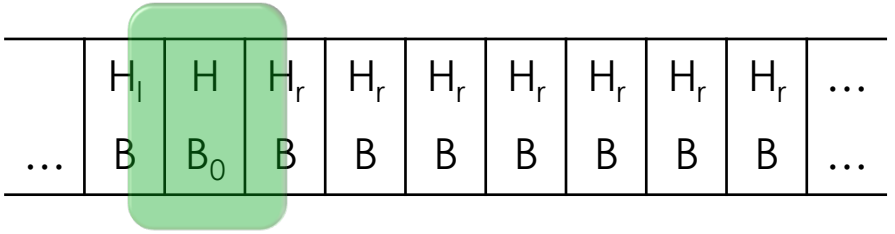

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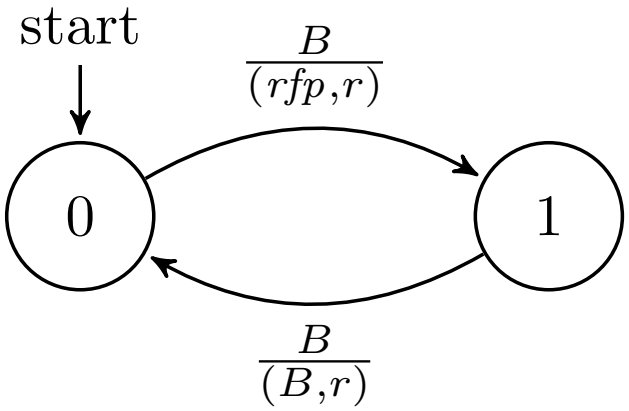

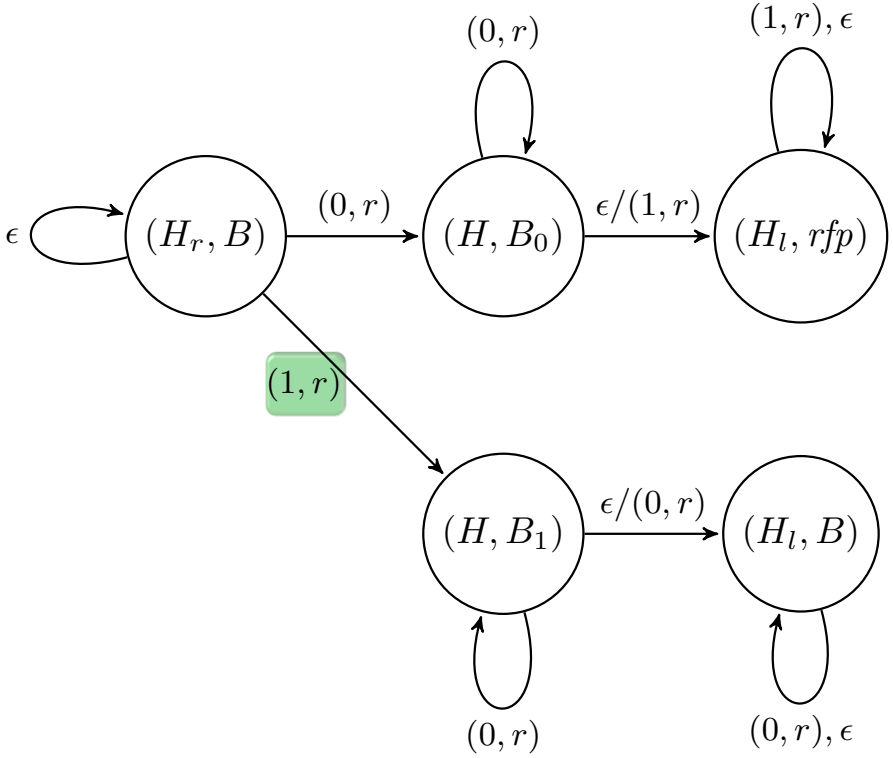

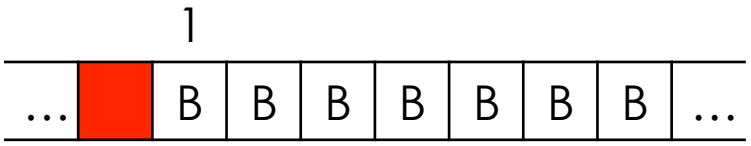

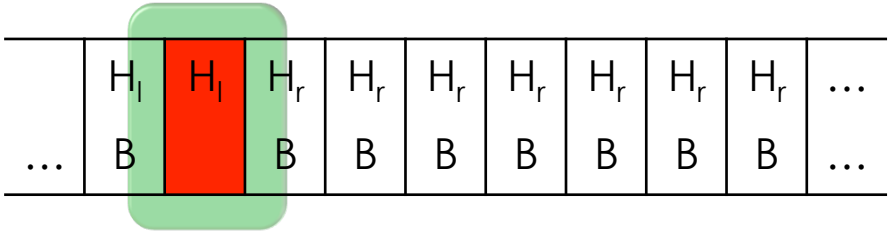

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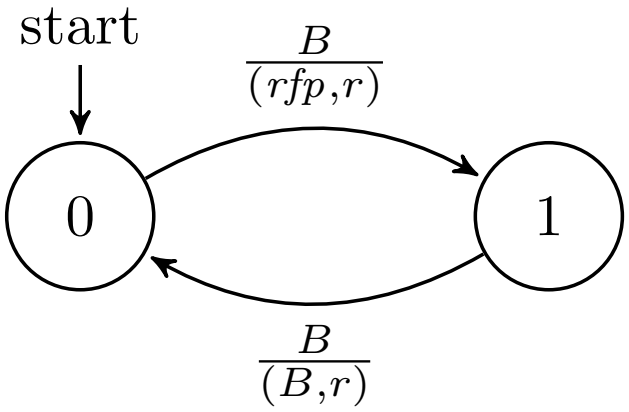

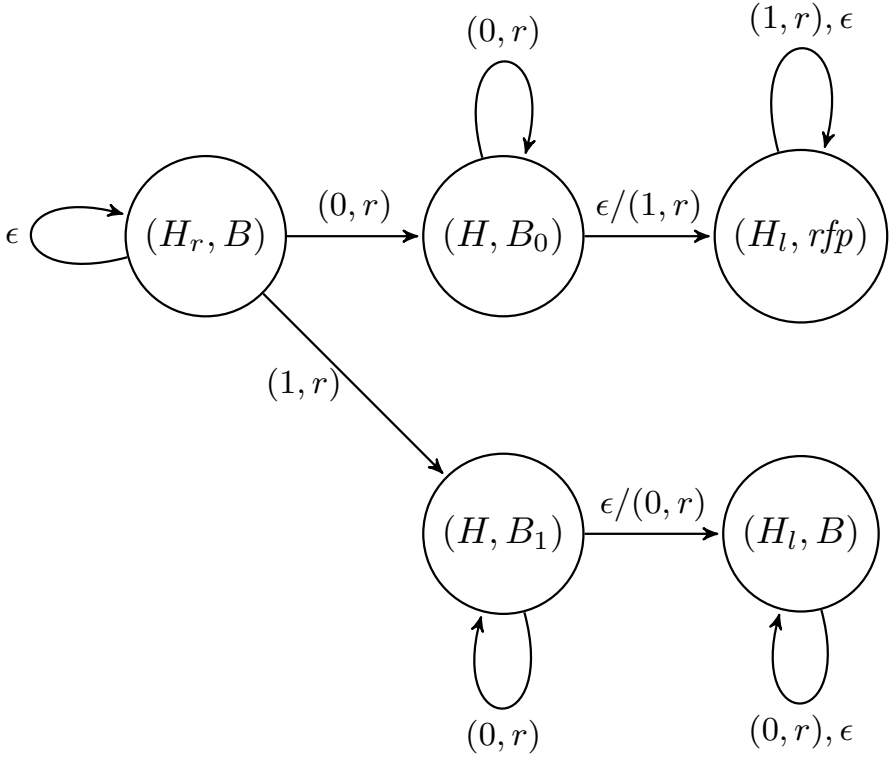

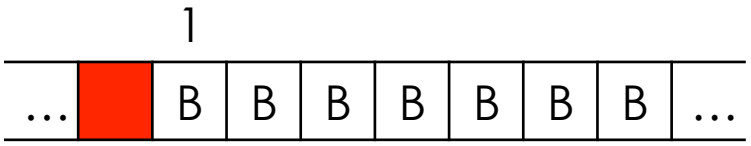

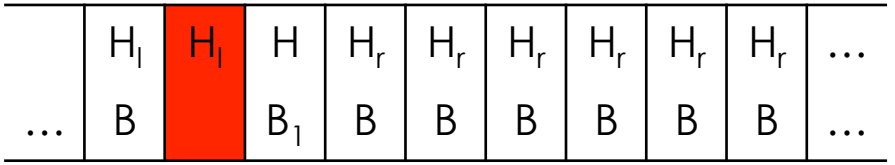

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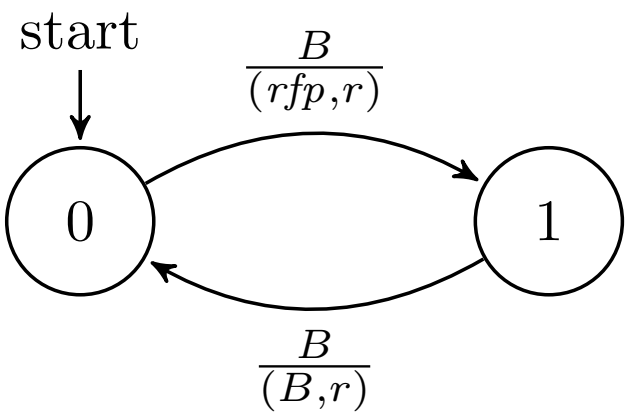
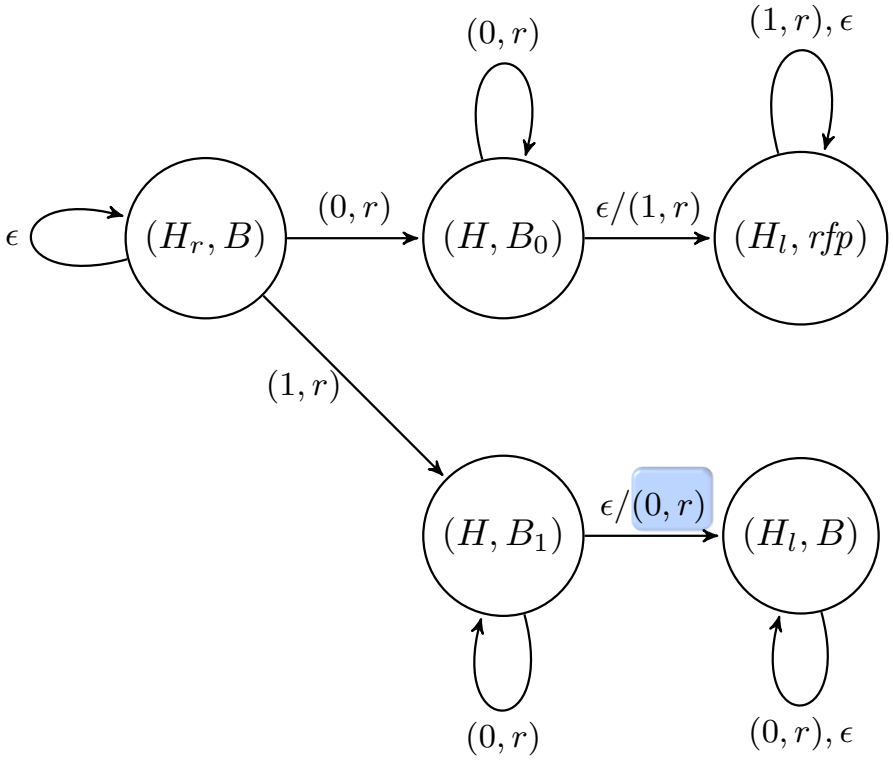
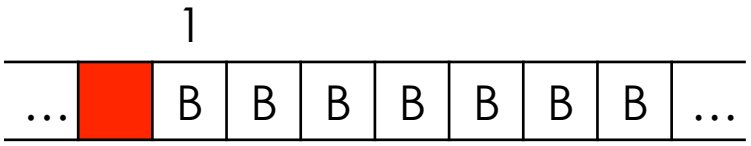
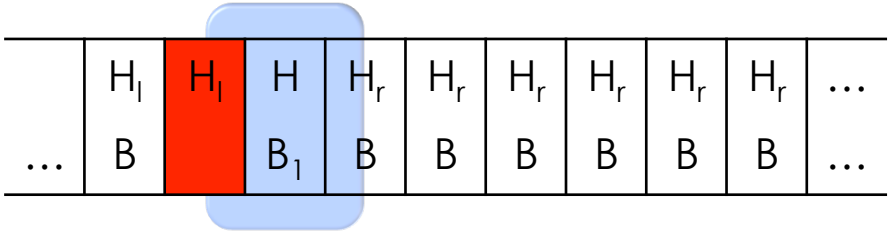
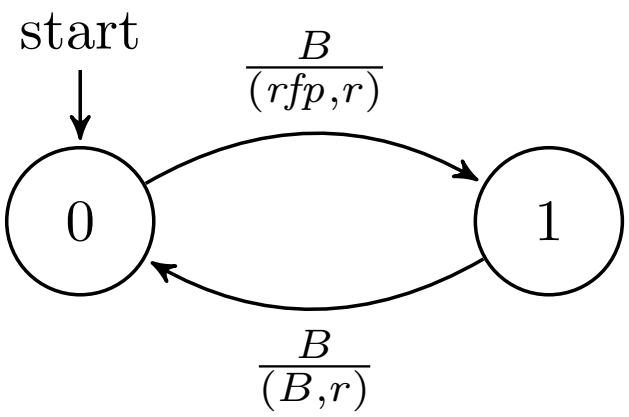


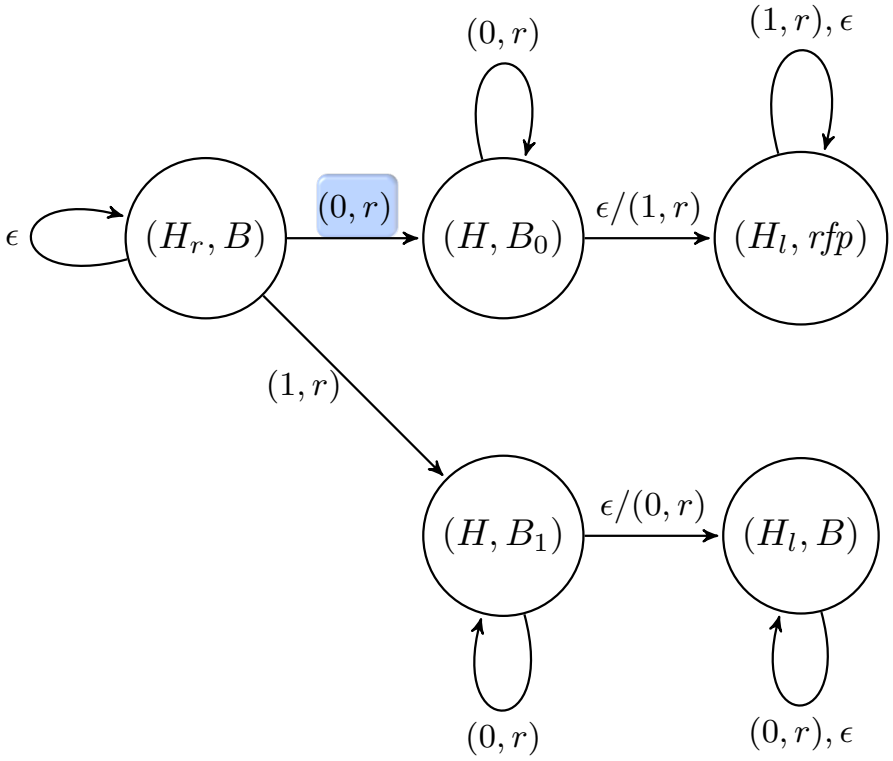


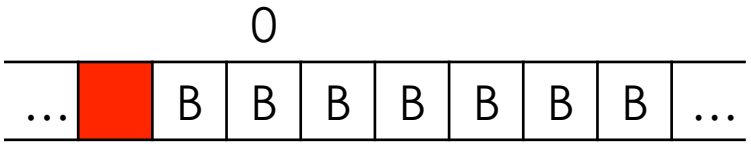


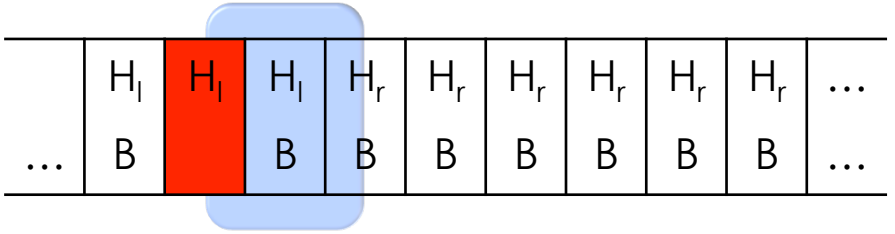


Example: Stripe Formation









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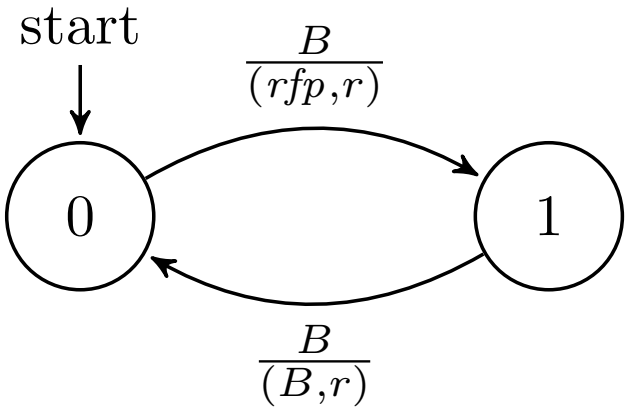

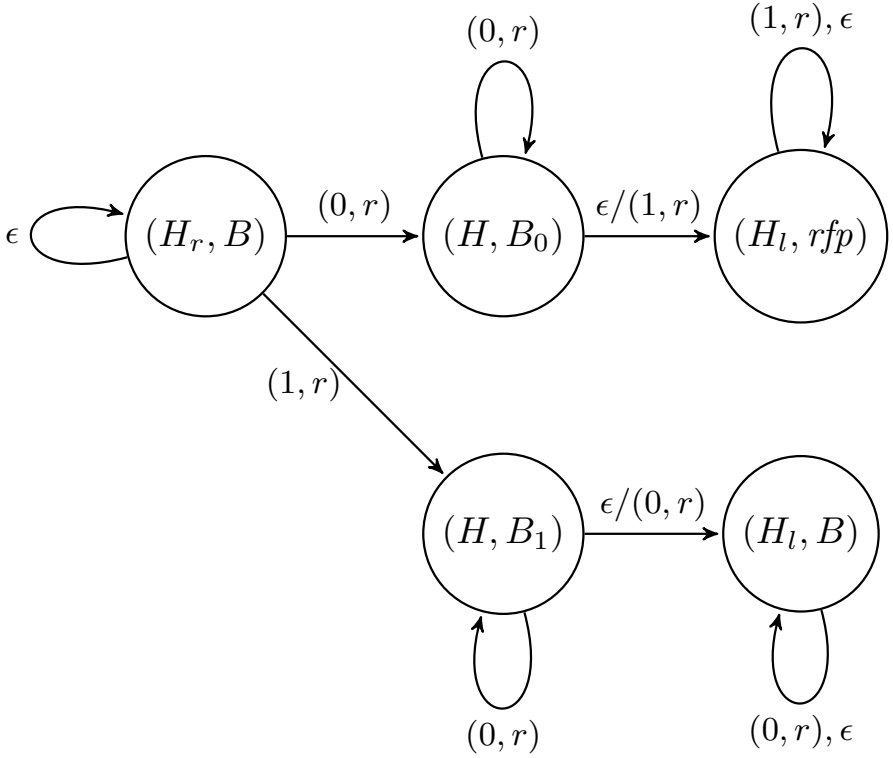

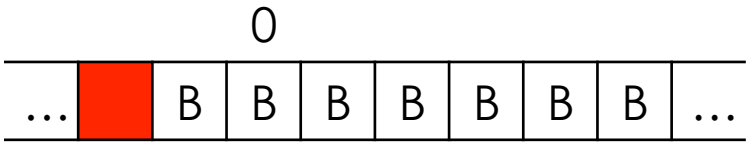

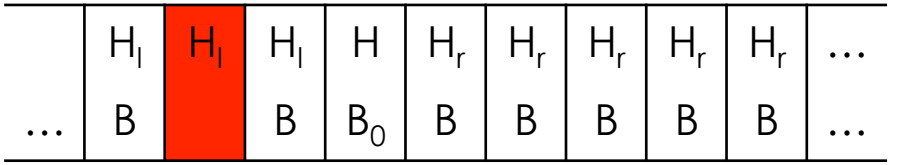

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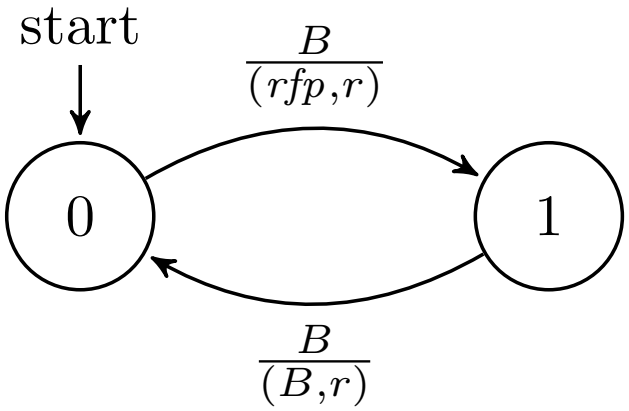

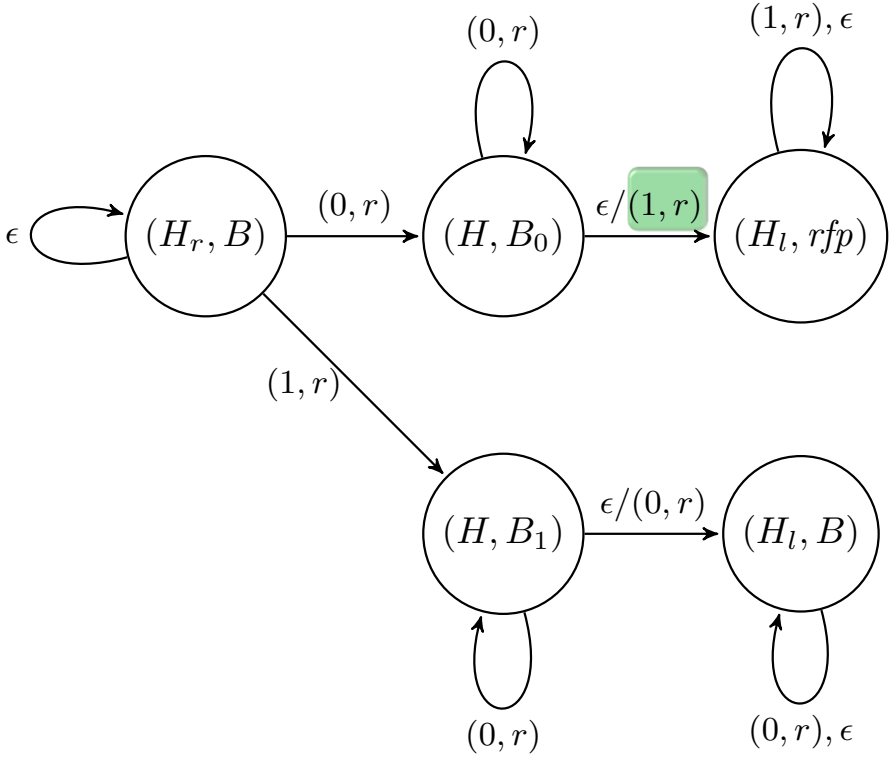

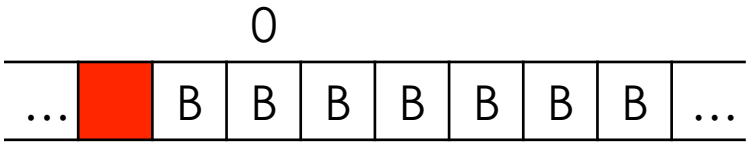

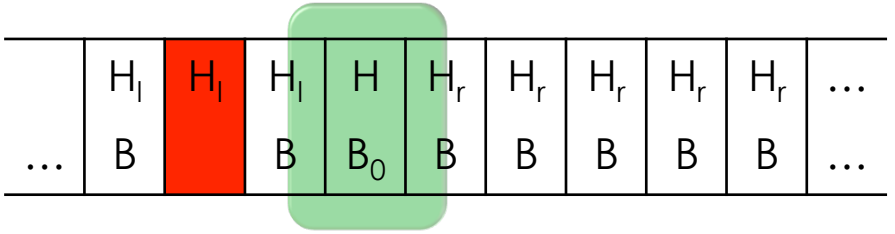

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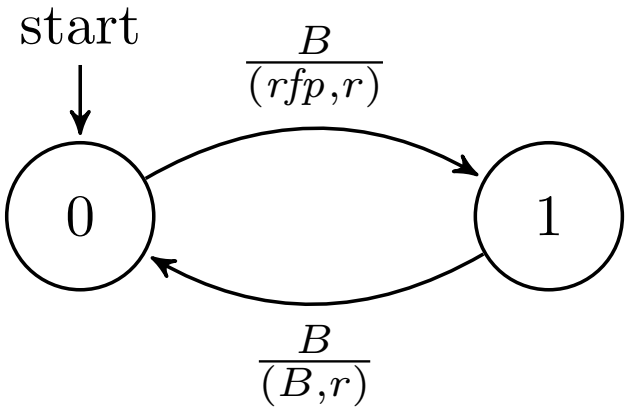

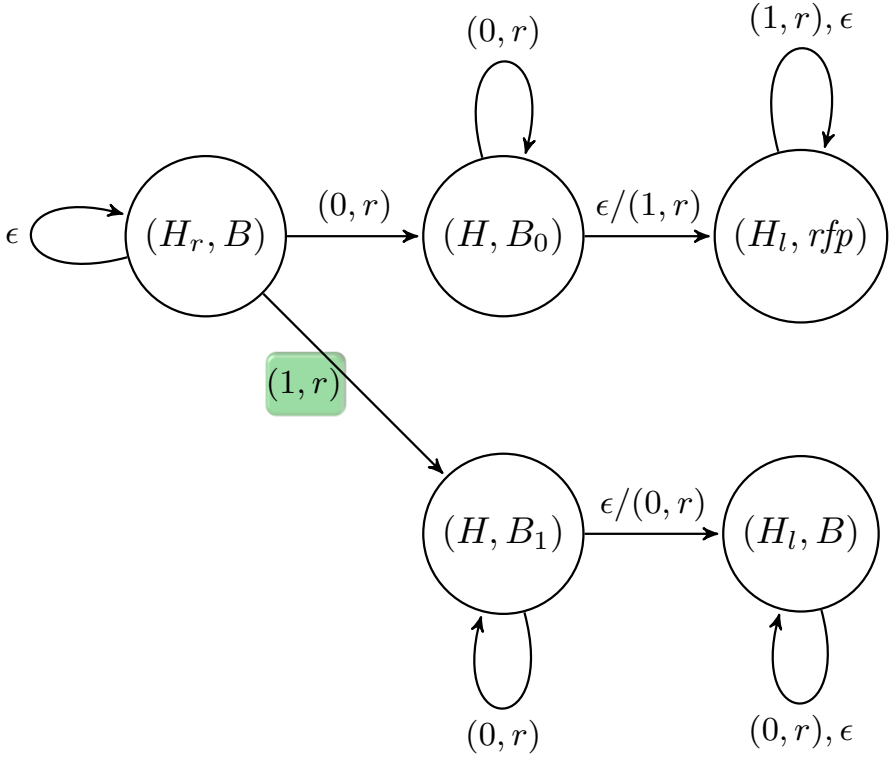

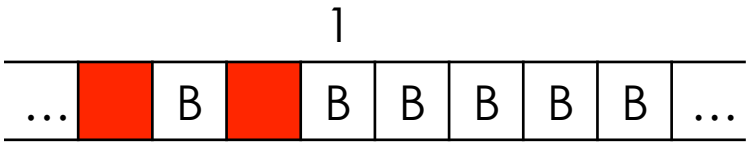

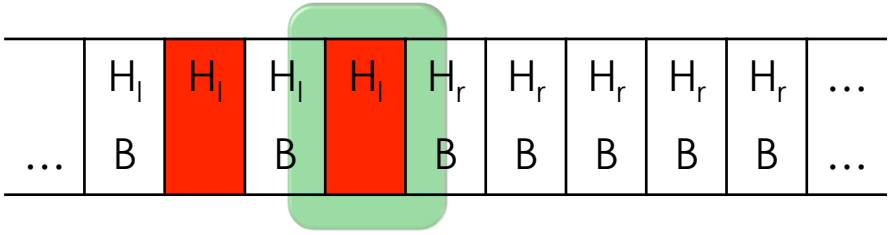

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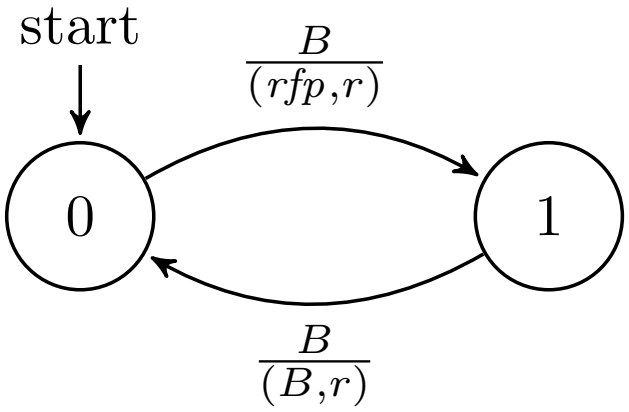

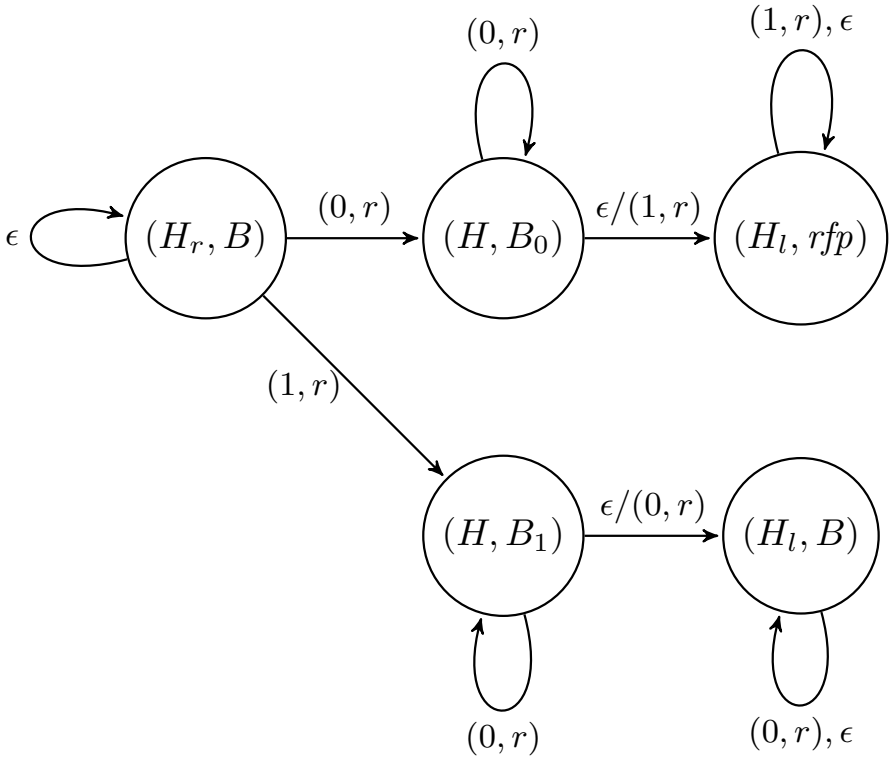

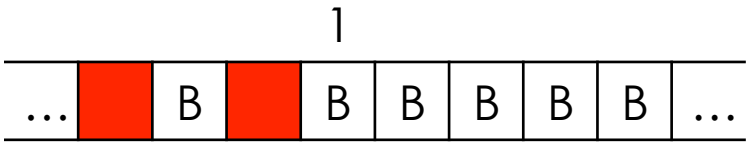

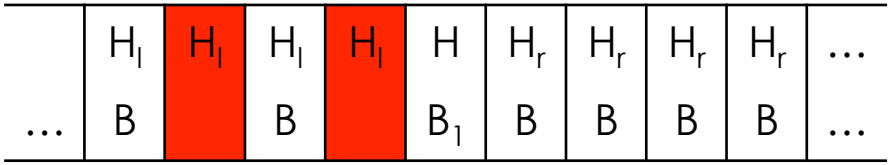

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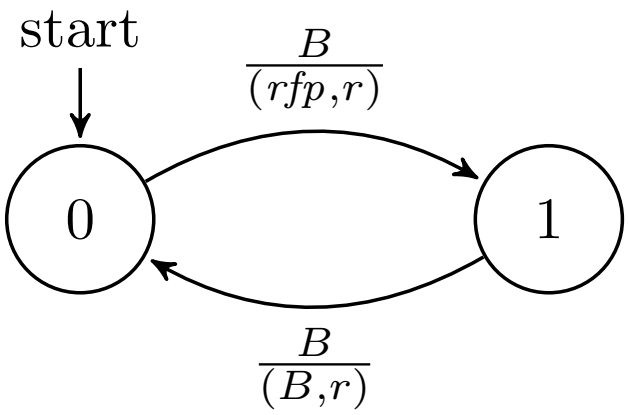

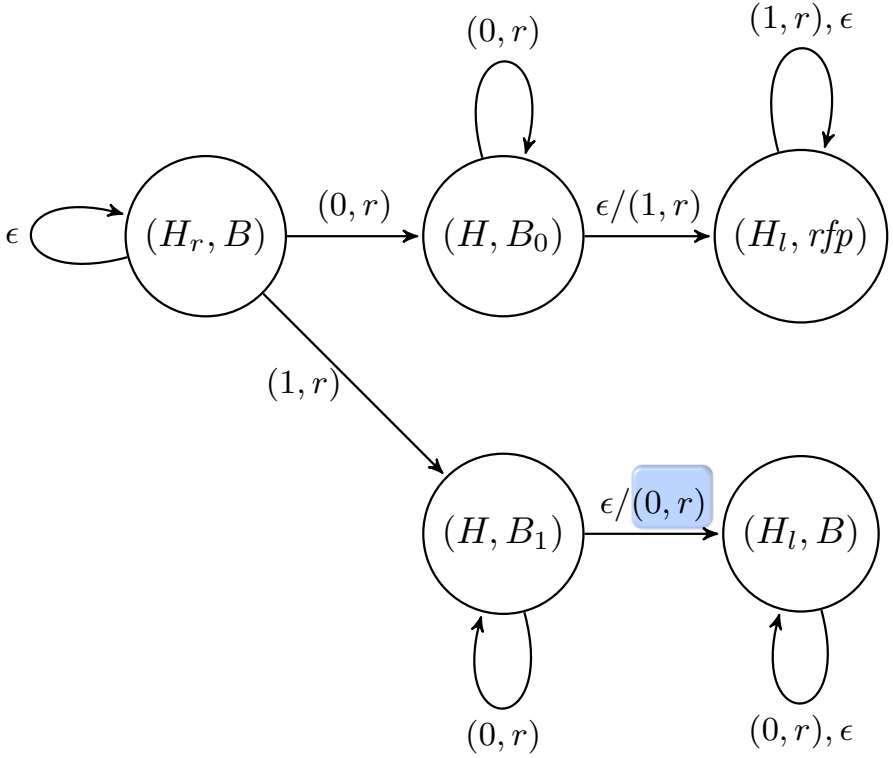

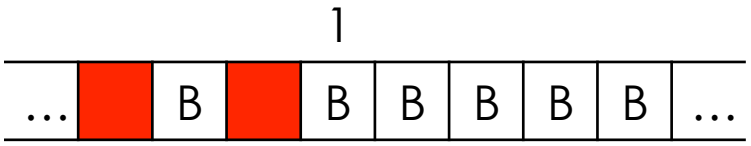

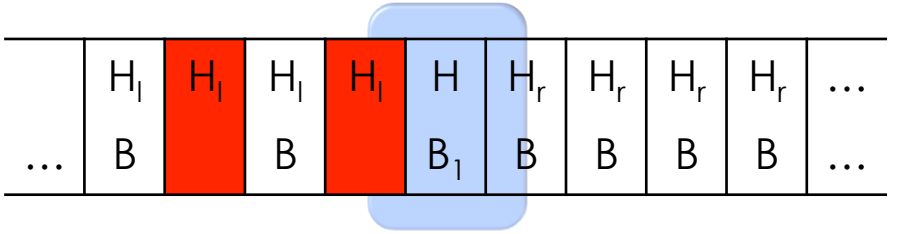

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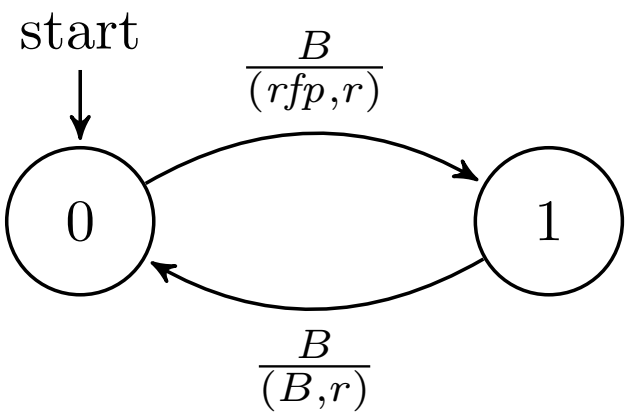

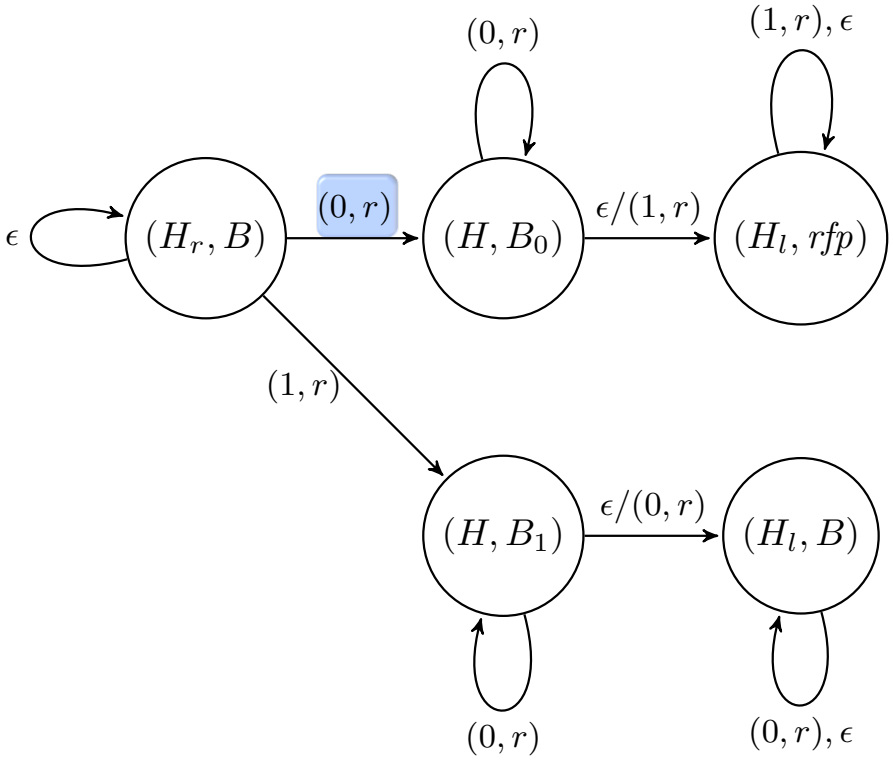

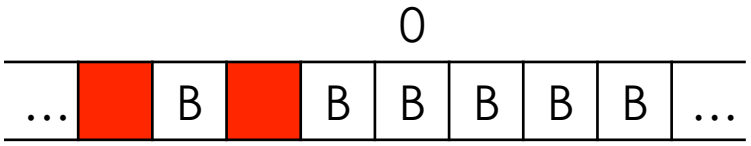

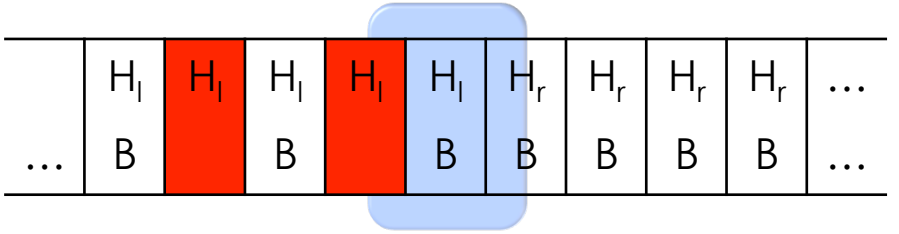

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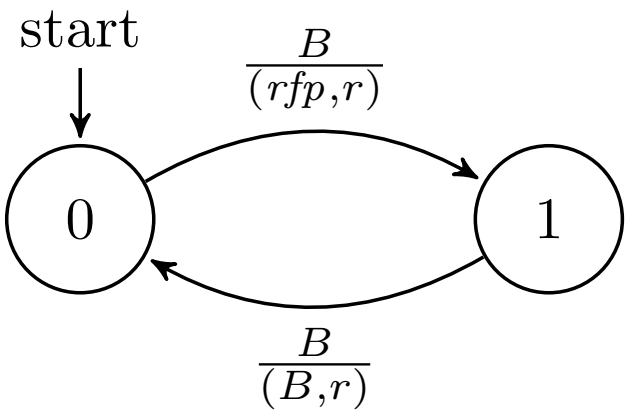

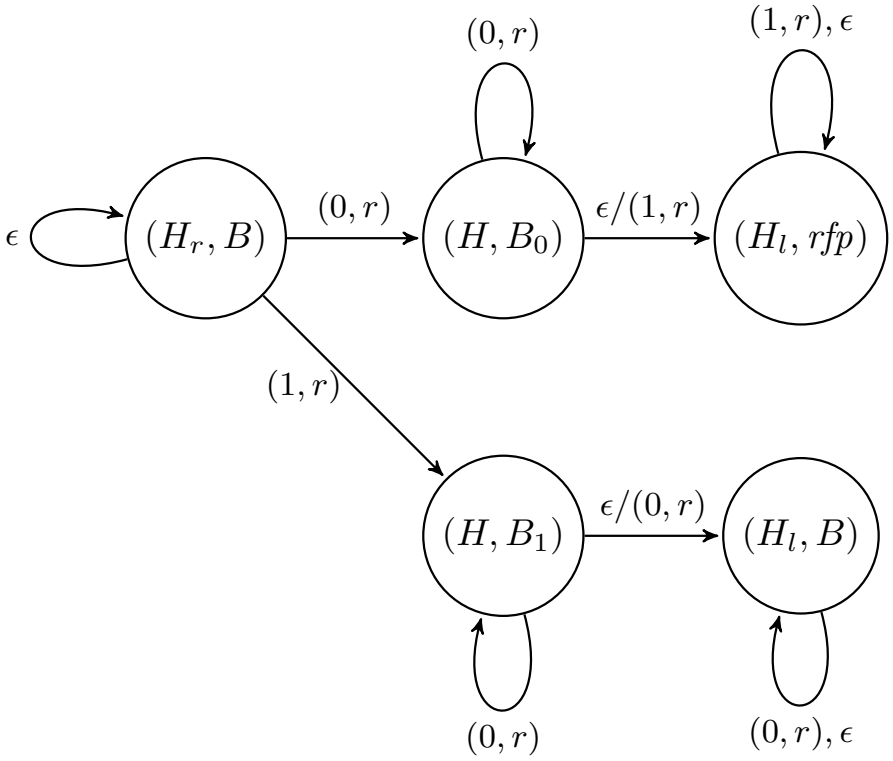

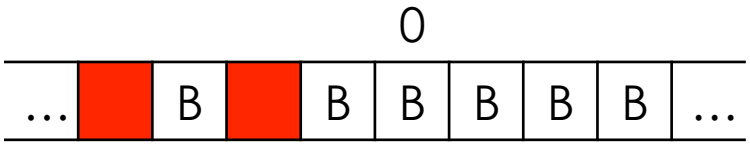

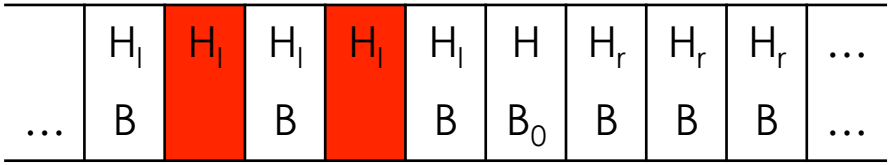

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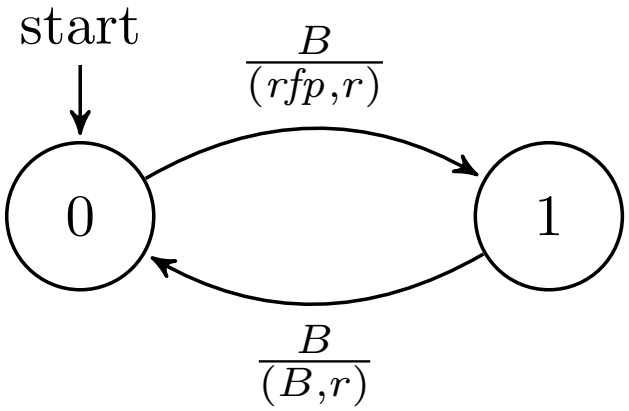

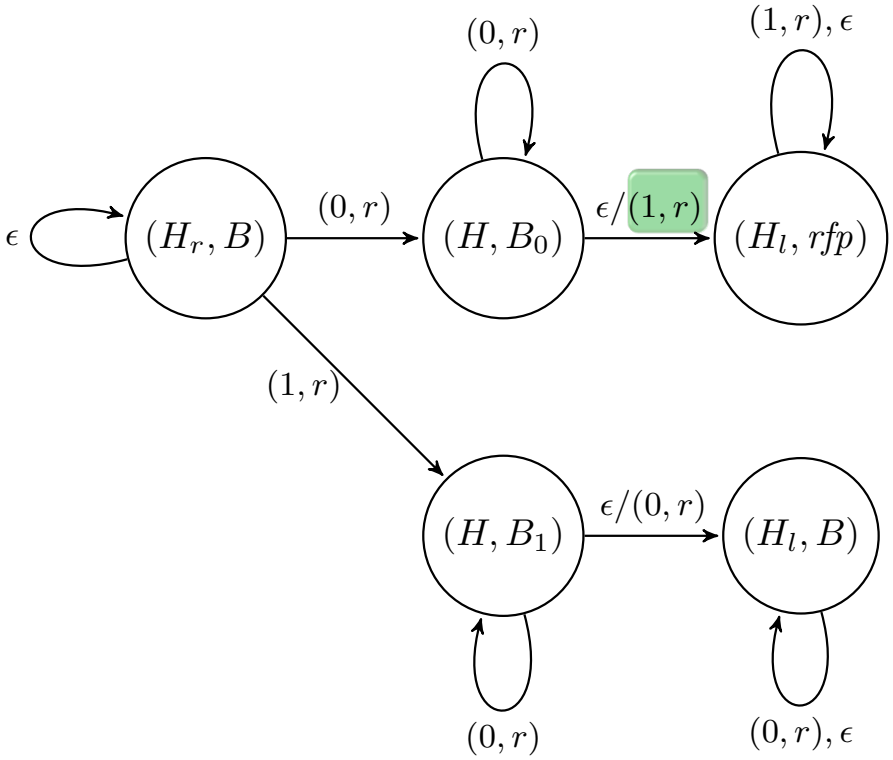

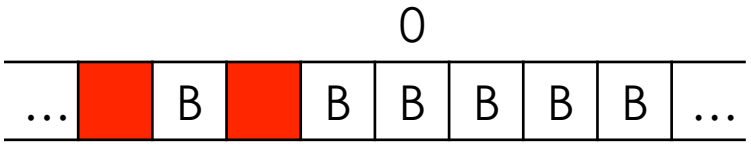

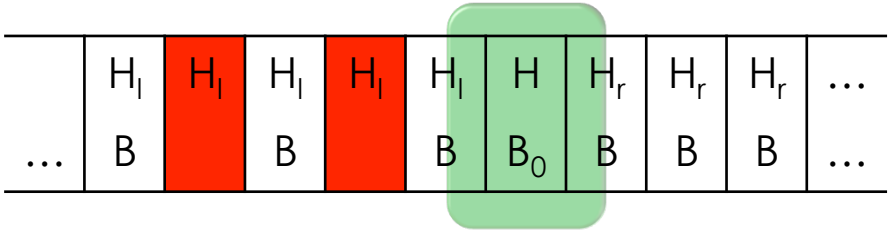

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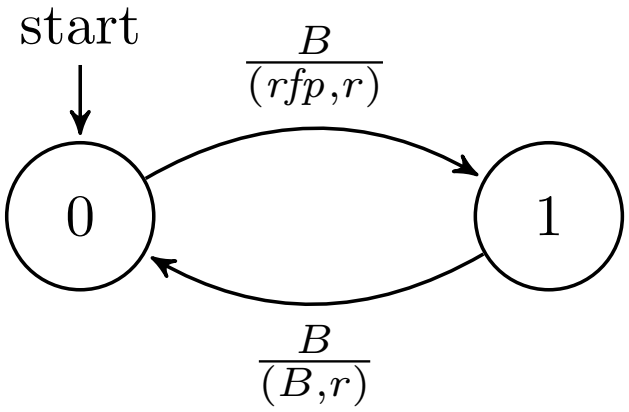

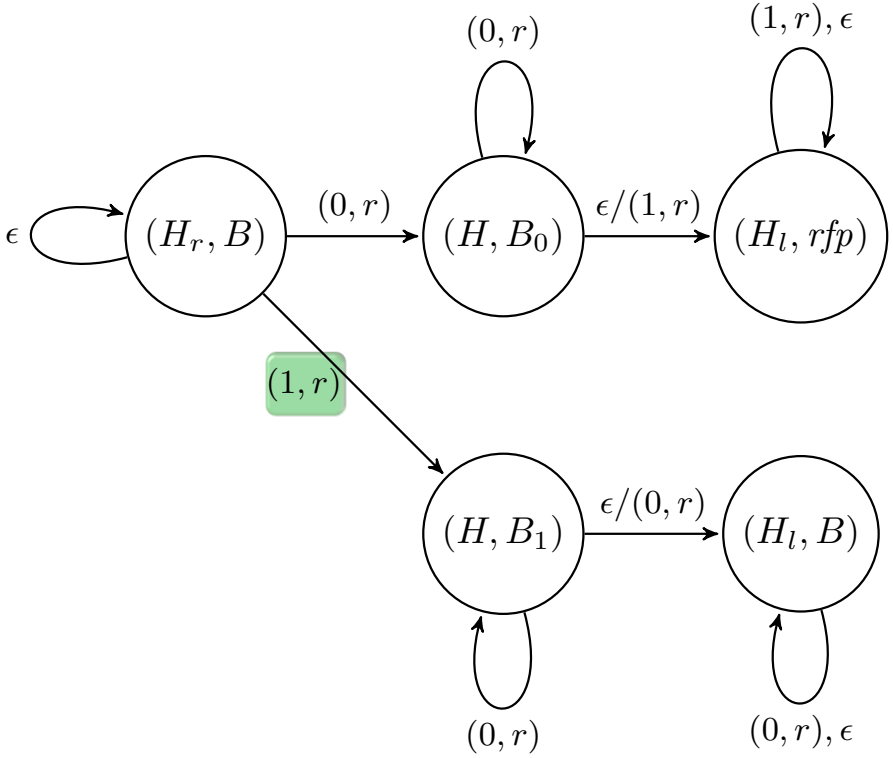

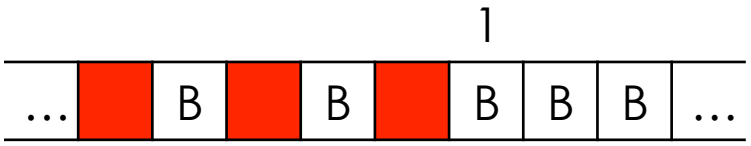

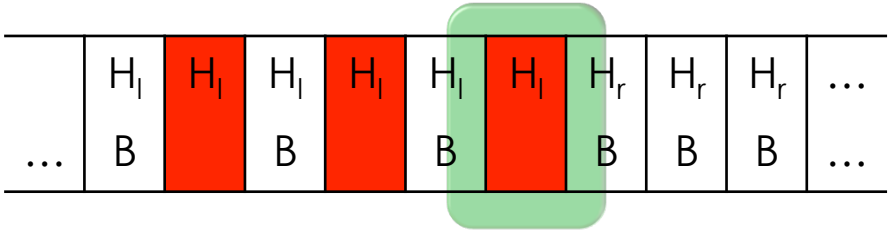

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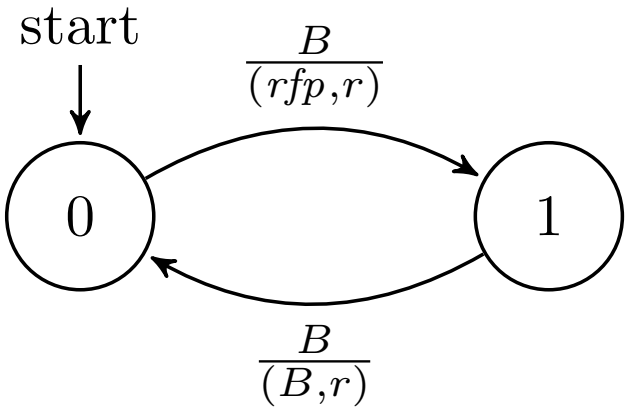

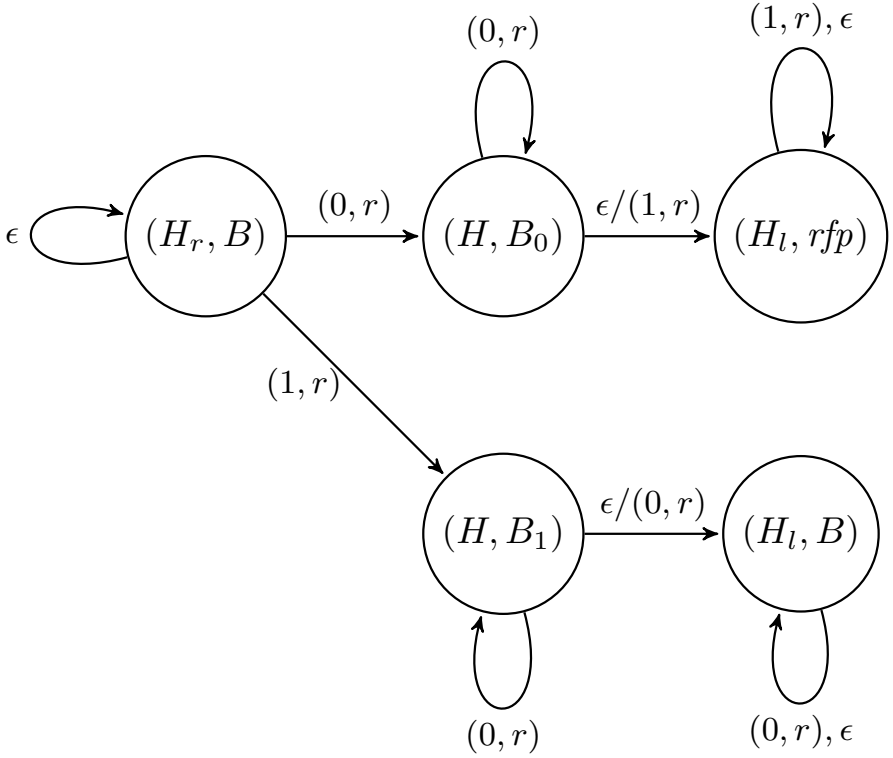

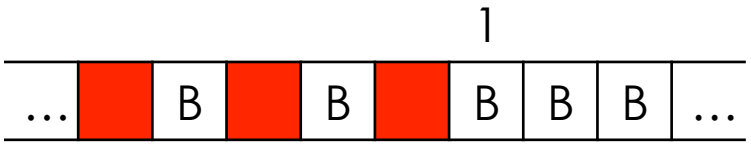

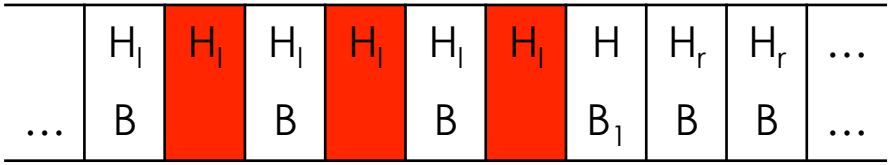

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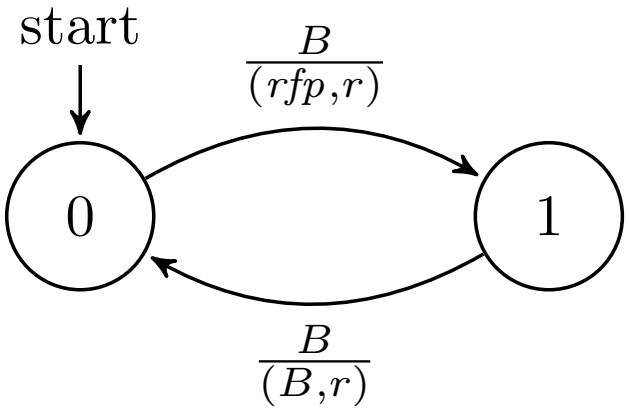

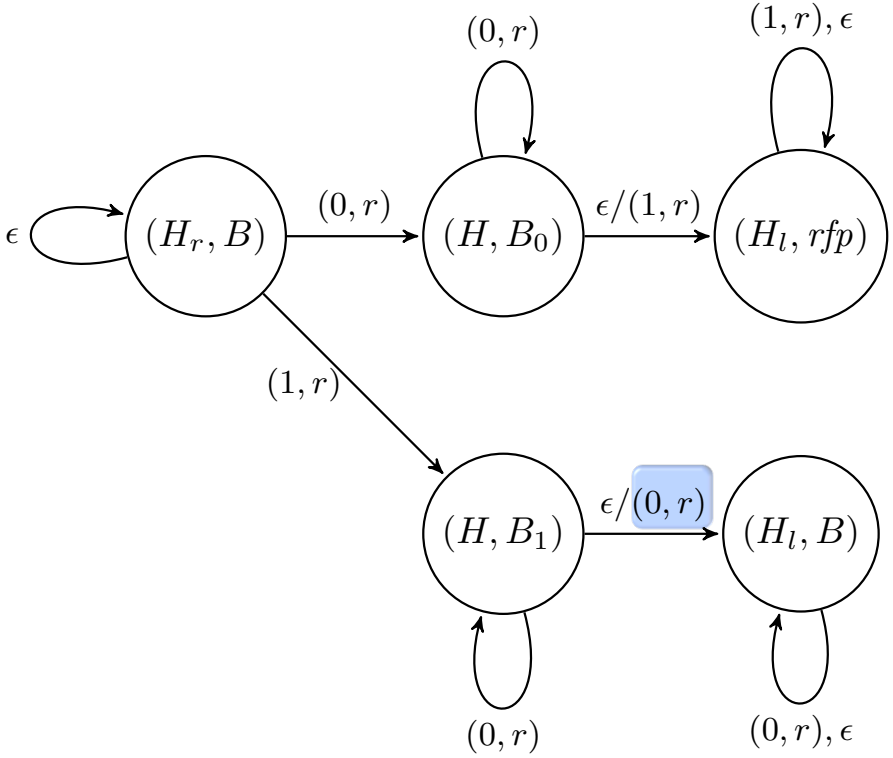

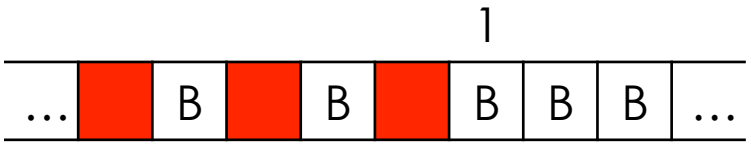

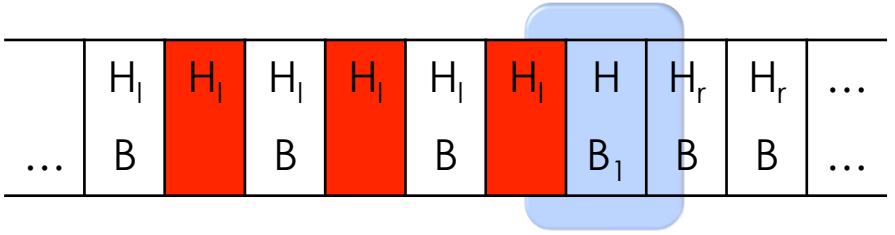

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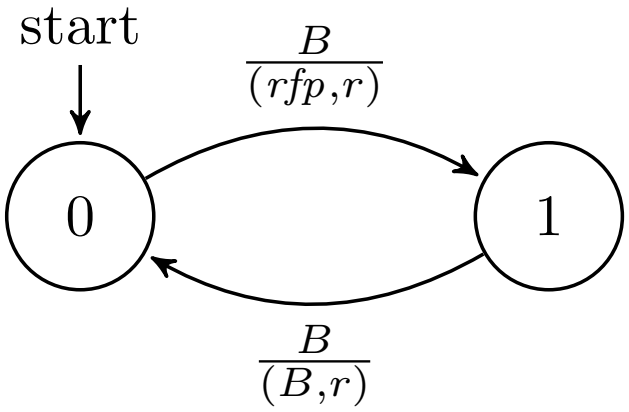

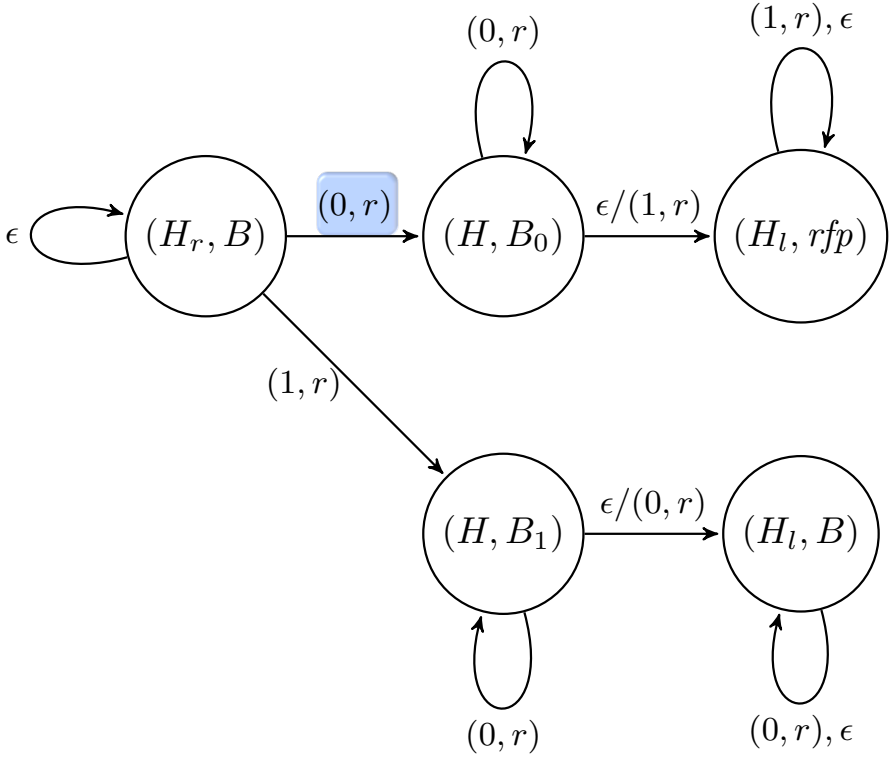

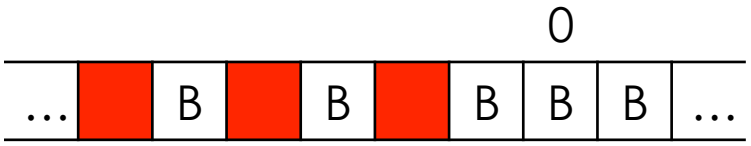

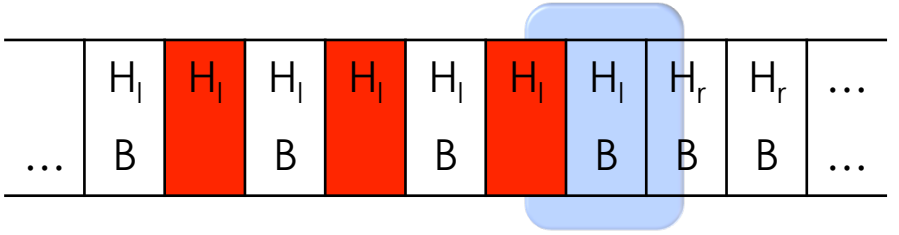

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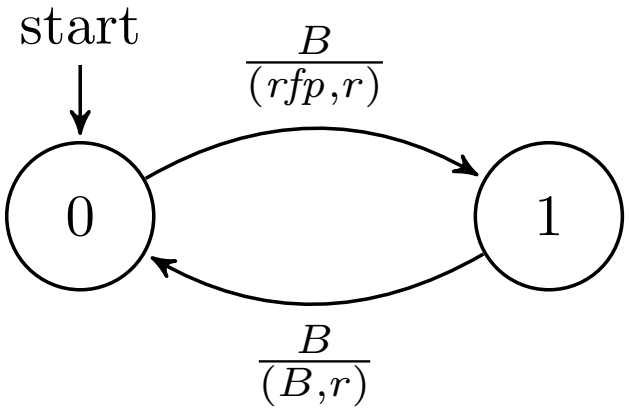
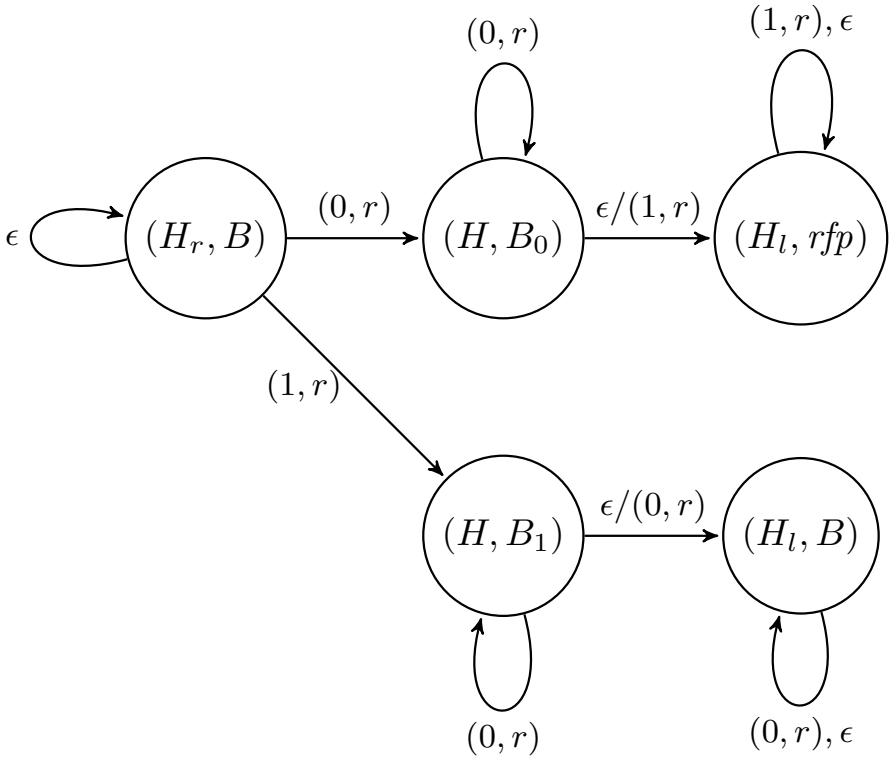
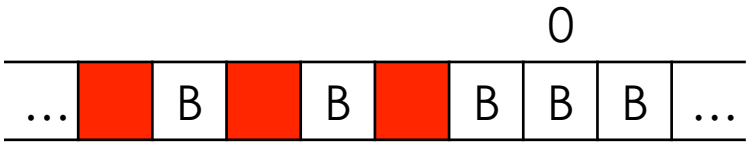
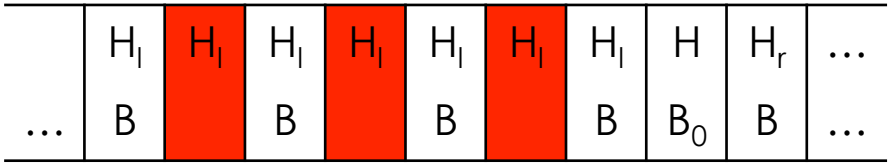
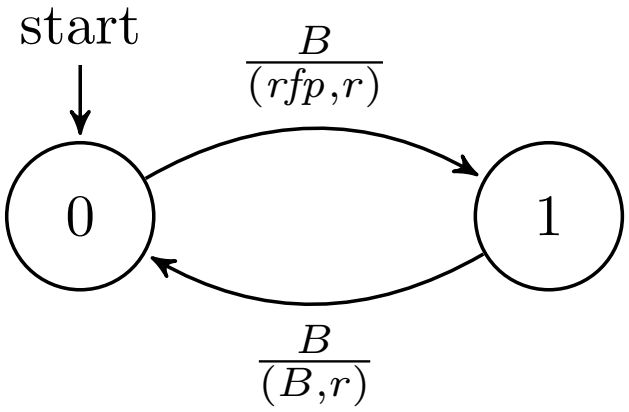


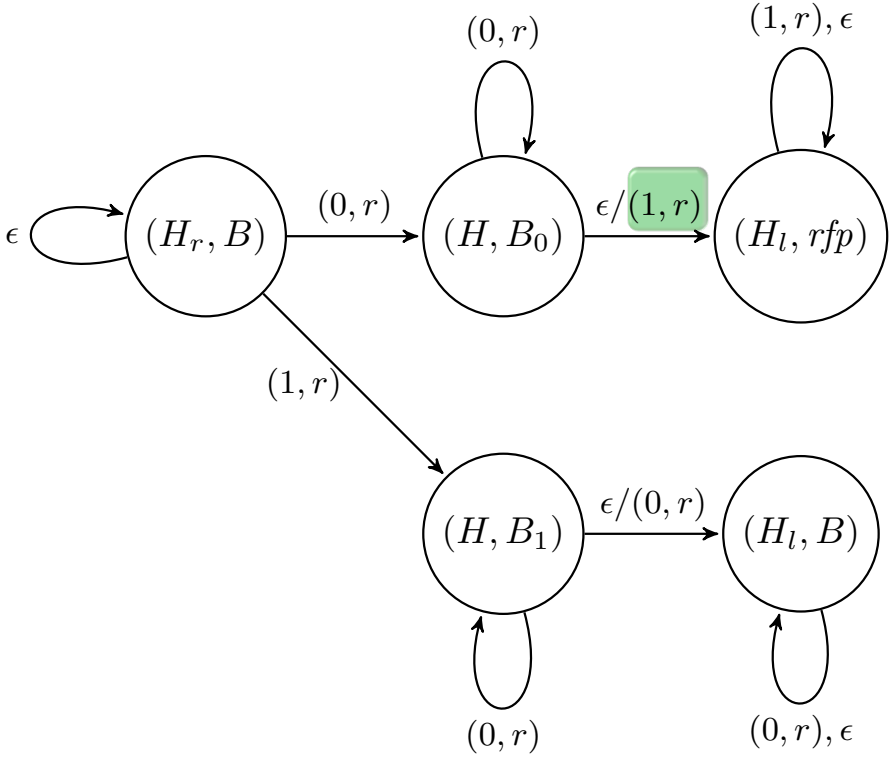


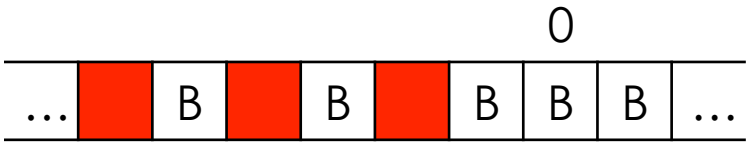


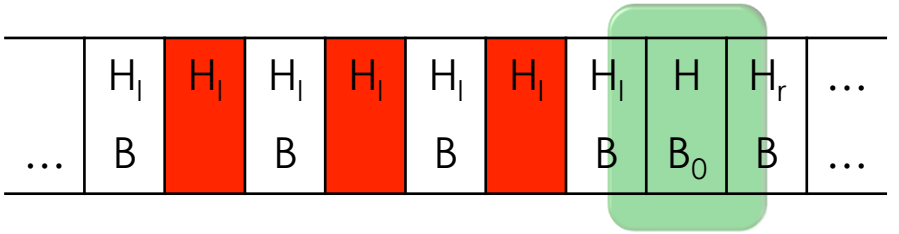


Example: Stripe Formation

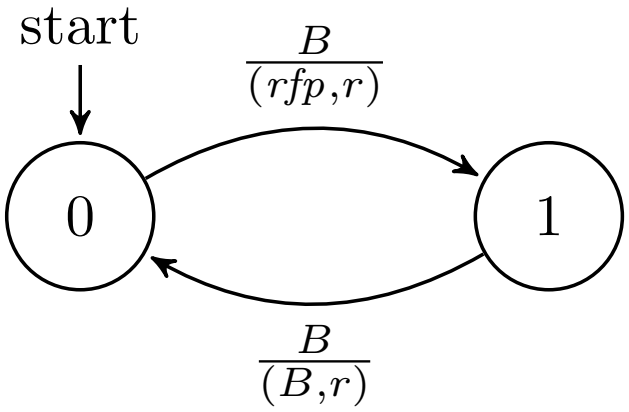


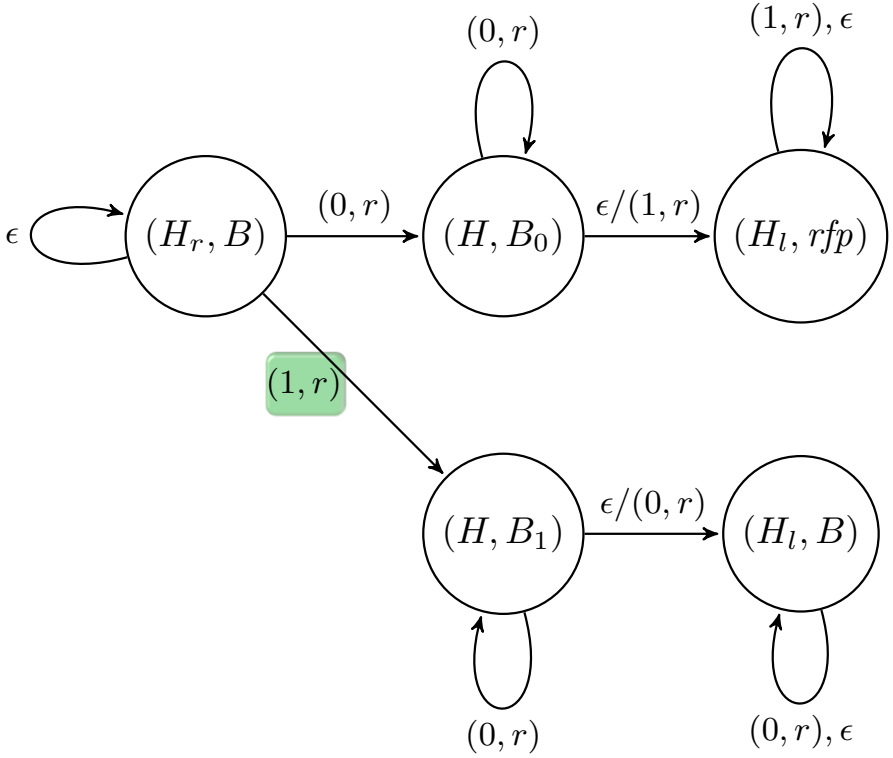


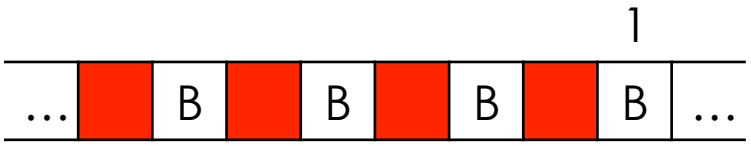


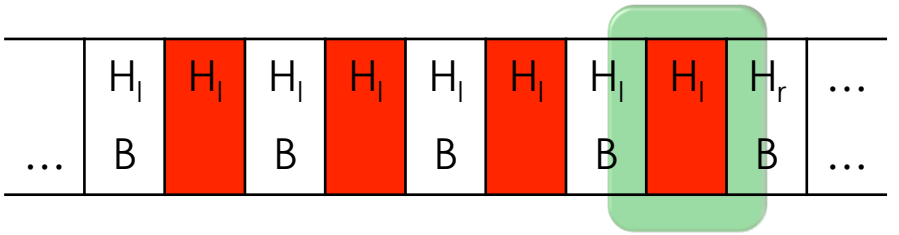


Example: Stripe Formation

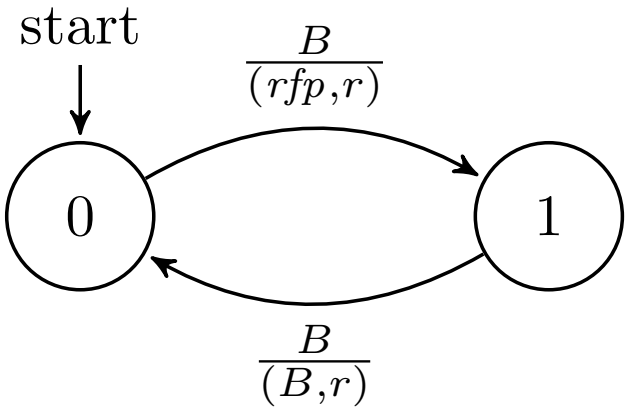


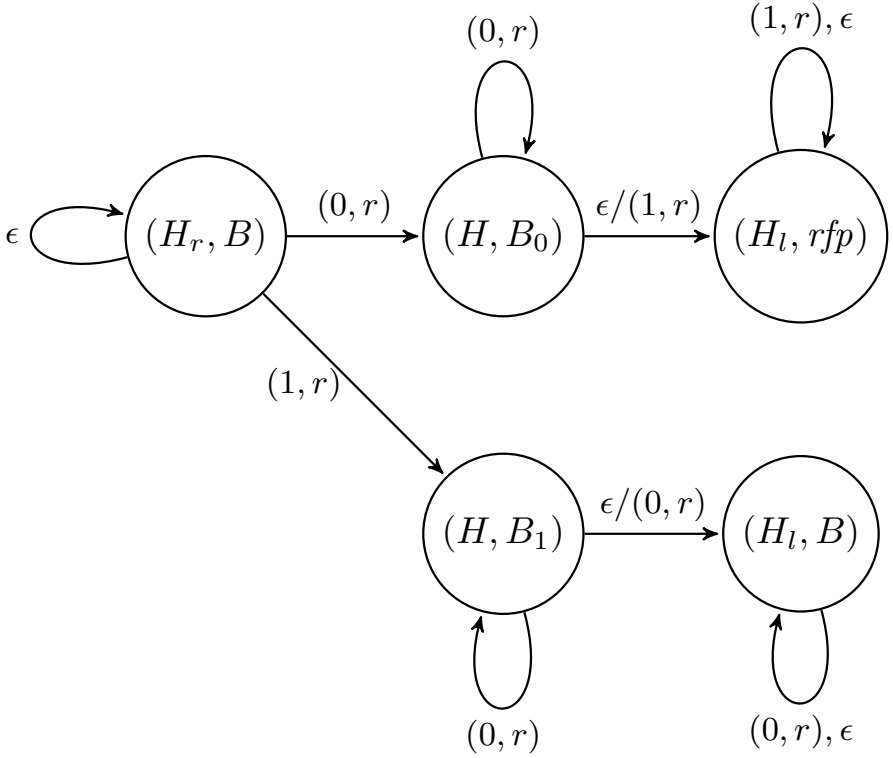


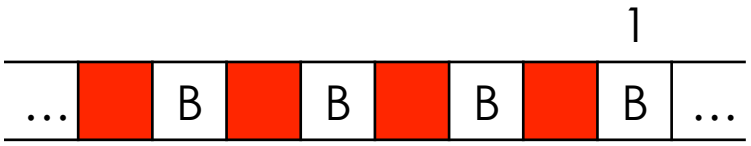


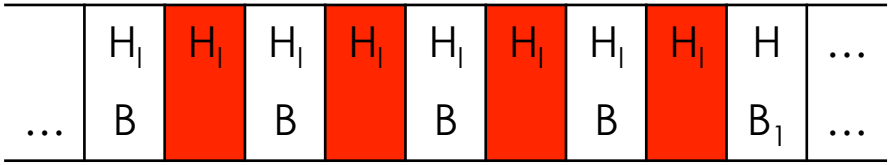


Example: Stripe Formation







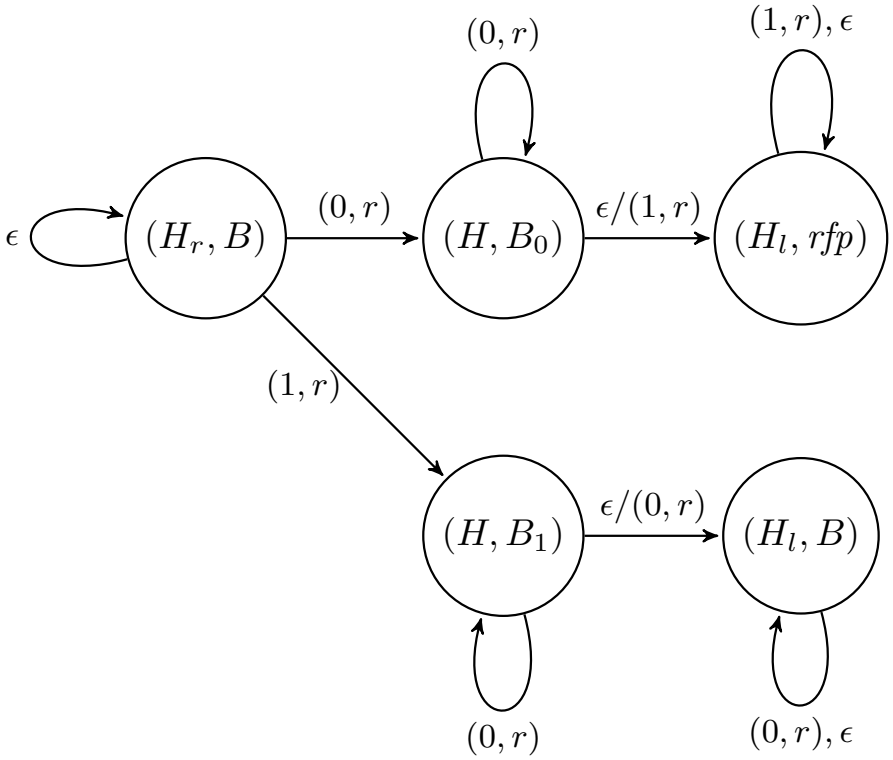


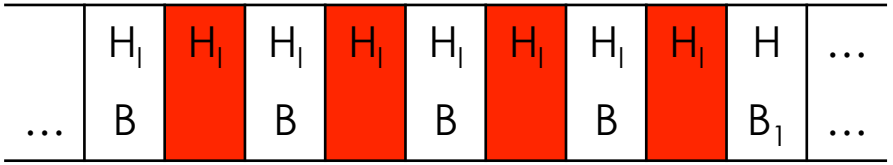
Example: Stripe Formation

```
S0r := signal(1,1);
S1r := signal(1,1);

HrB   := 0;
HB0   := 1;
Hlrfp := 2;
HB1   := 3;
HlB   := 4;

program stripes(x) := stripesInit(x)
     + reporter()                    sharing r,rfp
     + deltaEpsilon(HrB,S0r,HB0)     sharing r,rfp
     + deltaEpsilon(HrB,S1r,HB1)     sharing r,rfp
     + epsilon(HB0,Hlrfp,S1r)        sharing r,rfp
     + epsilon(HB1,HlB,S0r)          sharing r,rfp
```





gro

Download gro and find and excellent tutorial here:

http://depts.washington.edu/soslab/gro

gro

See Professor Eric Klavins' "Introduction to gro" slides here:

https://depts.washington.edu/soslab/sbf12/5-Gro.pdf

For additional examples, see slides 12-20 here (Hill functions, chemostats, and program composition):

https://depts.washington.edu/soslab/sbf12/8-Modeling-Gene-Regulation.pdf

And check out the "examples" directory in gro.