



**UNIVERSITÀ DEGLI STUDI
DI MILANO-BICOCCA**



A
MILANO TEAM LTD*
Production

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A long time ago in papers far,
far away....

Theorem IV

UNBOUNDED DEPTH

Confluent P systems with active membranes with UNBOUNDED-DEPTH membrane structures characterise PSPACE in polynomial time...

Theorem V

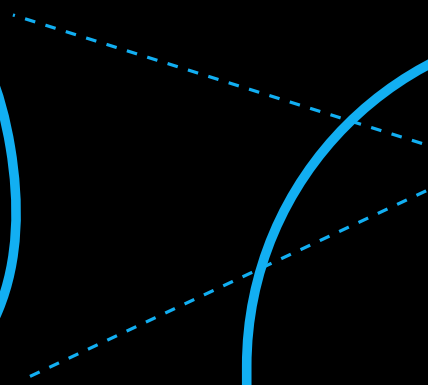
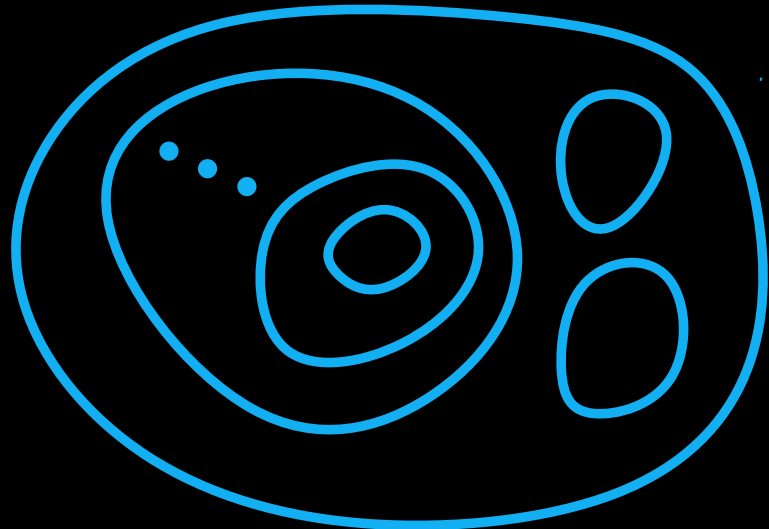
SHALLOW DEPTH

Confluent P systems with active membranes with SHALLOW (i.e., depth-1) membrane structures characterise $P^{\#P}$ in polynomial time....

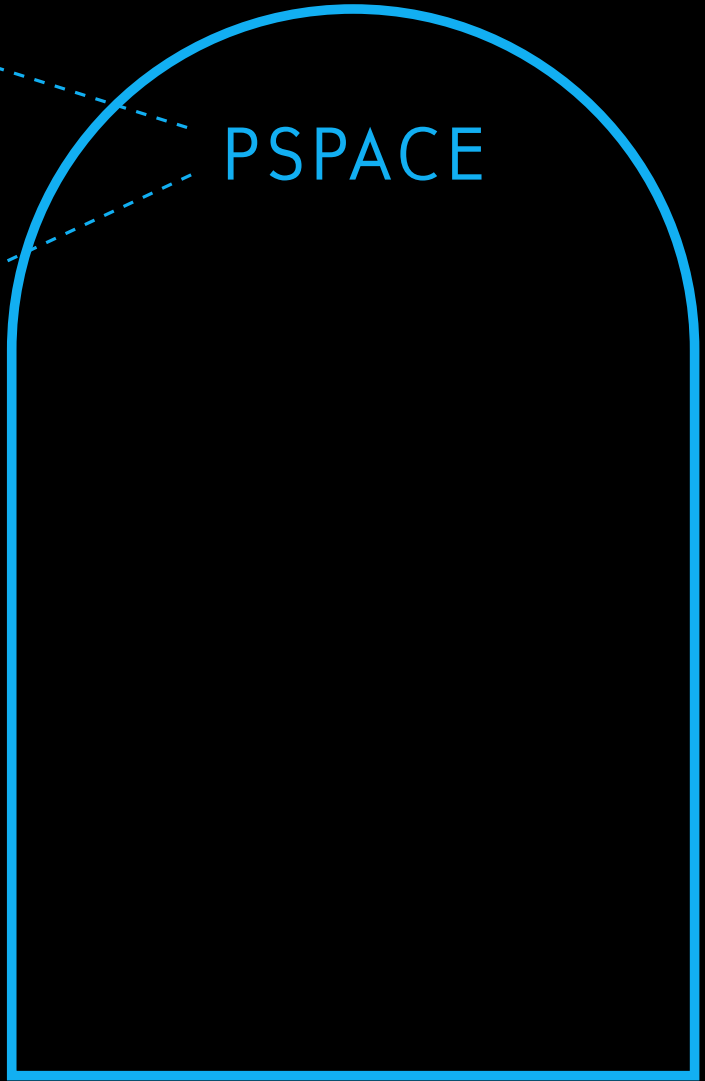
Theorem VI

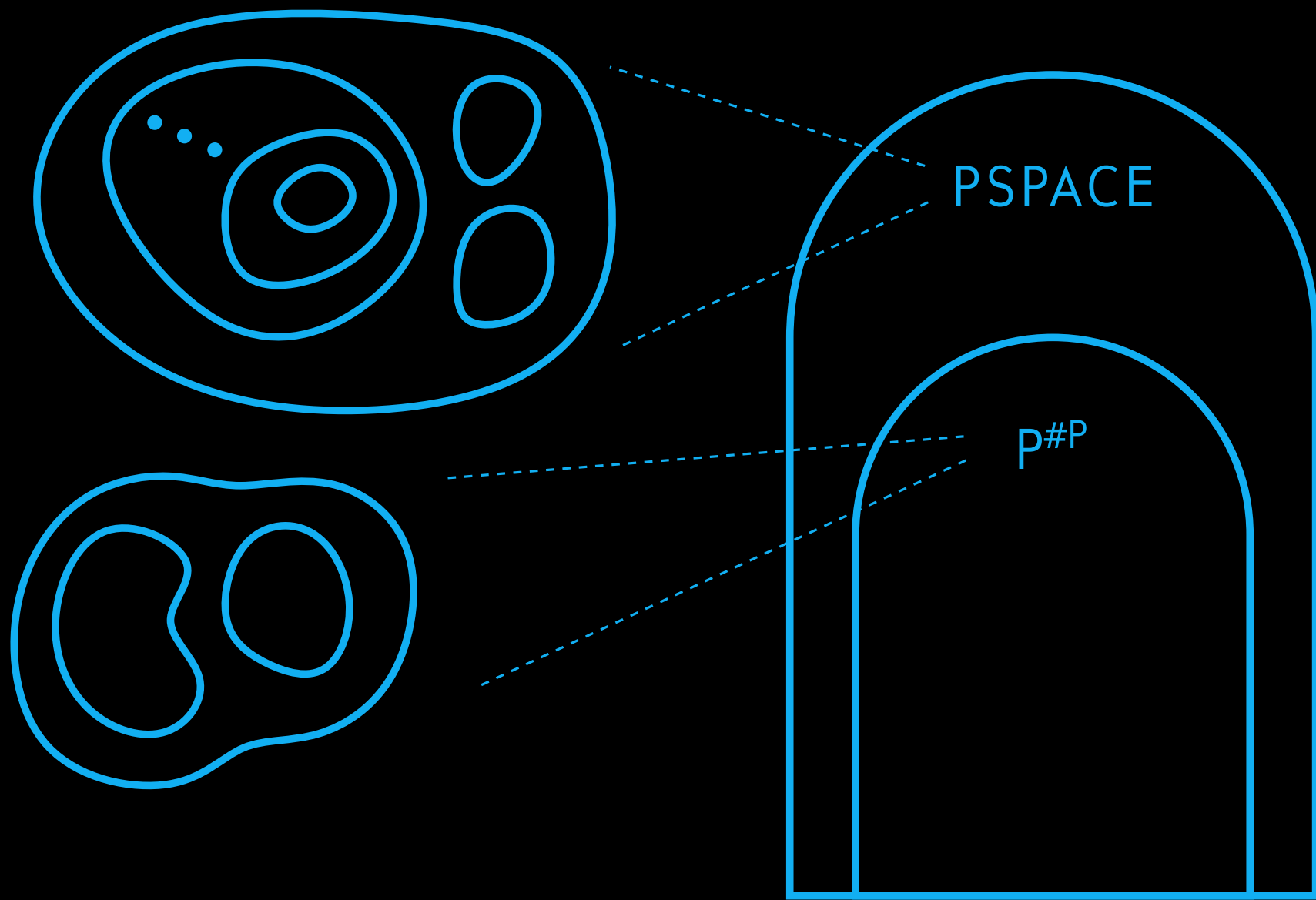
MILANO THEOREM

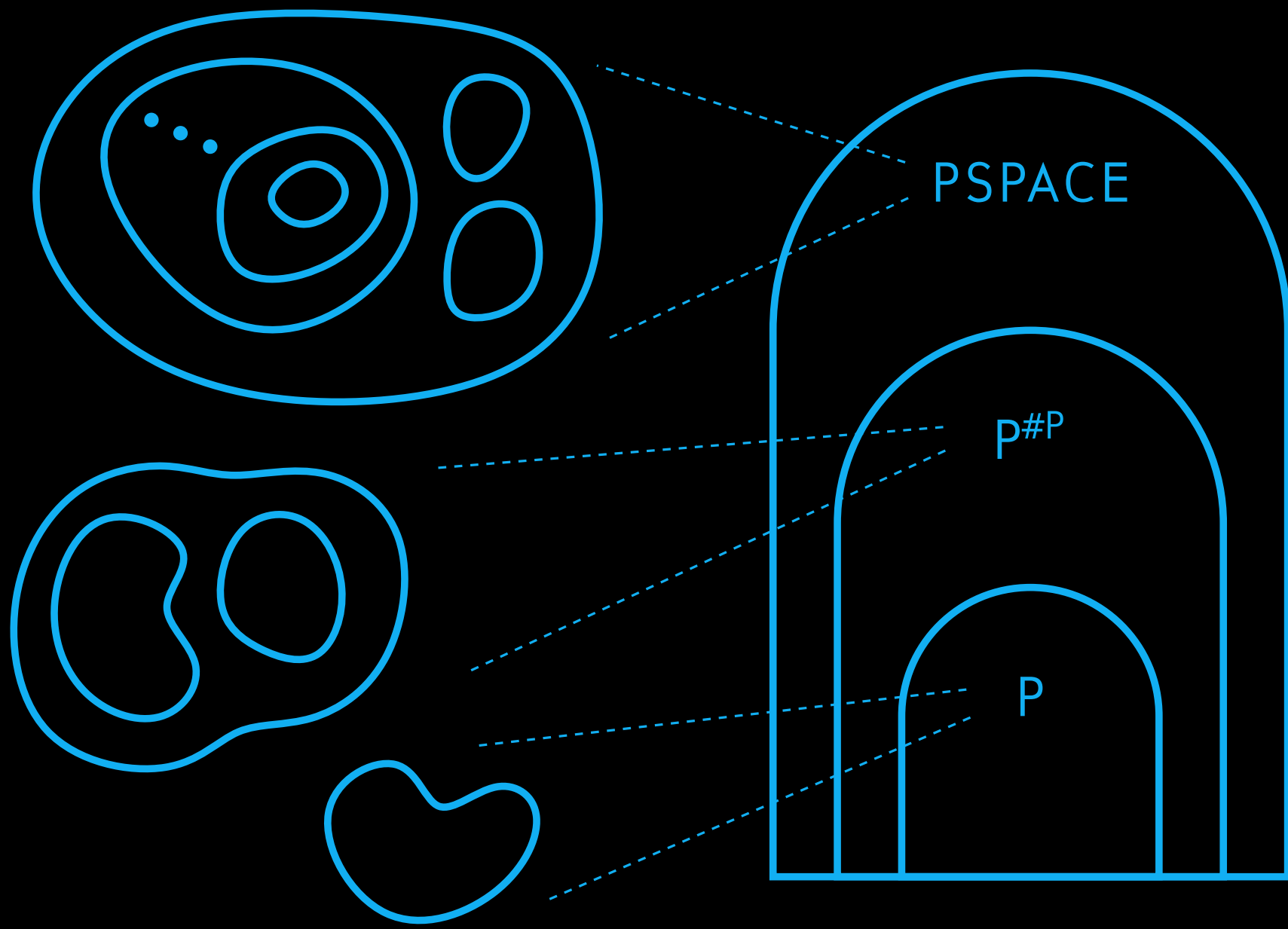
Confluent P systems with active membranes with DEPTH-0 membrane structures (i.e., single membranes) characterise P in polynomial time....



PSPACE







$PSPACE$

$P\#P$

P

SHALLOW
NON-CONFLUENT
P SYSTEMS

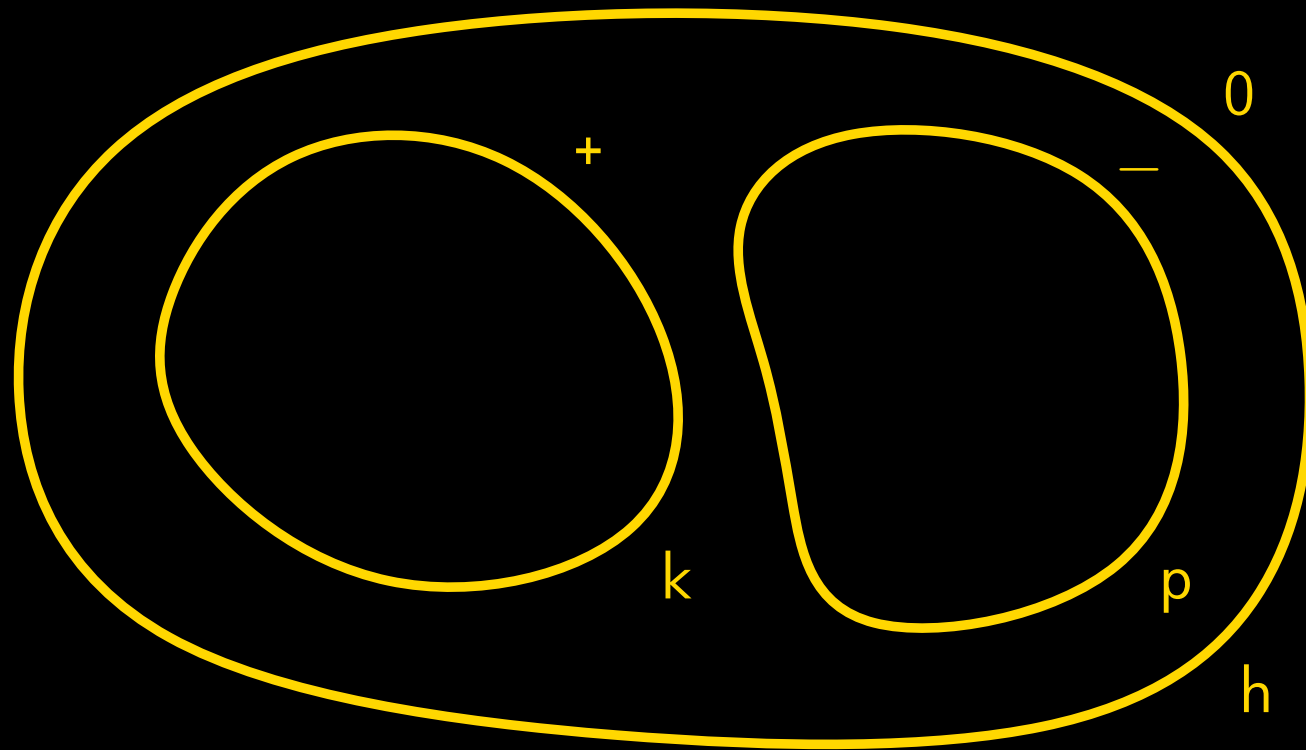
Theorem 1

A NEW RESULT

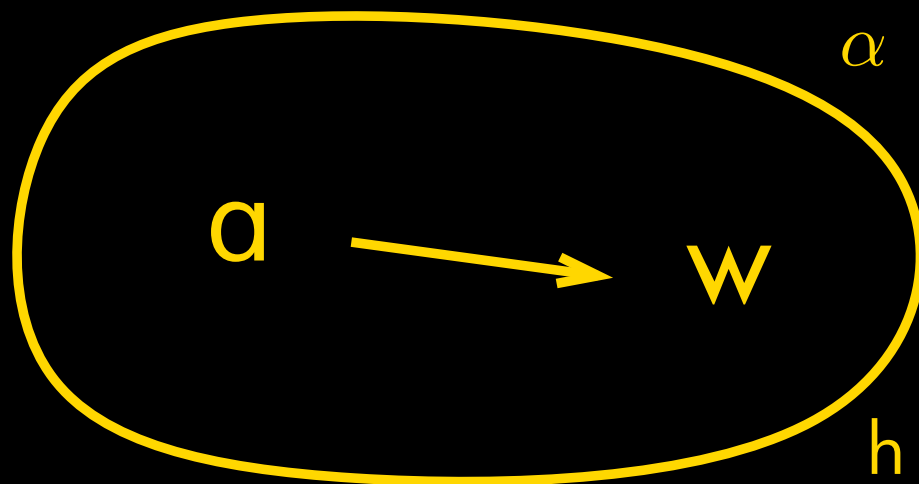
SHALLOW NON-CONFLUENT P systems with active membranes can simulate polynomial-SPACE nondeterministic Turing machines in polynomial TIME, and thus solve all PSPACE problems and restore efficiency to the galaxy....

Definition 1

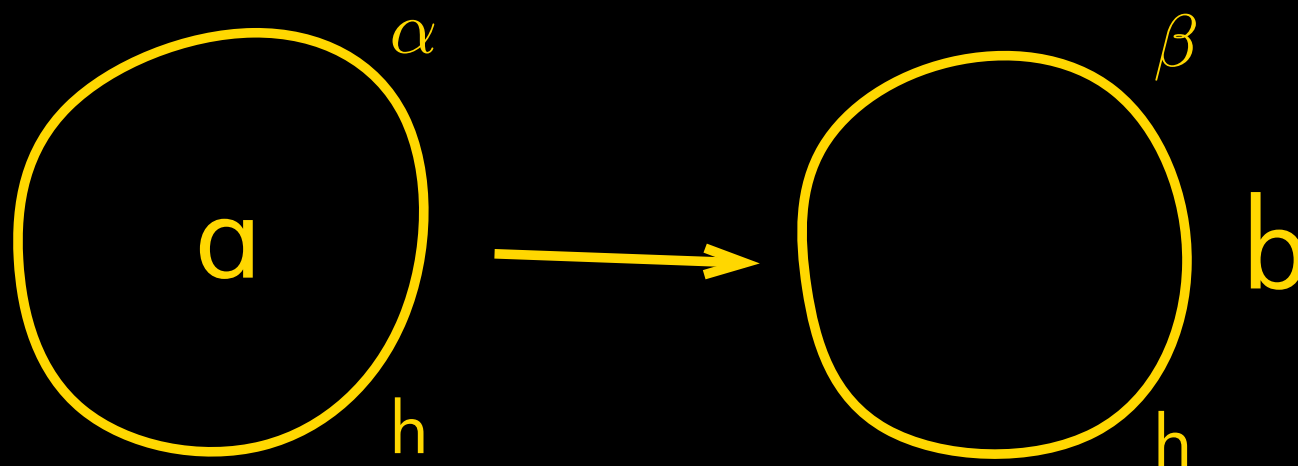
P SYSTEMS WITH ACTIVE MEMBRANES



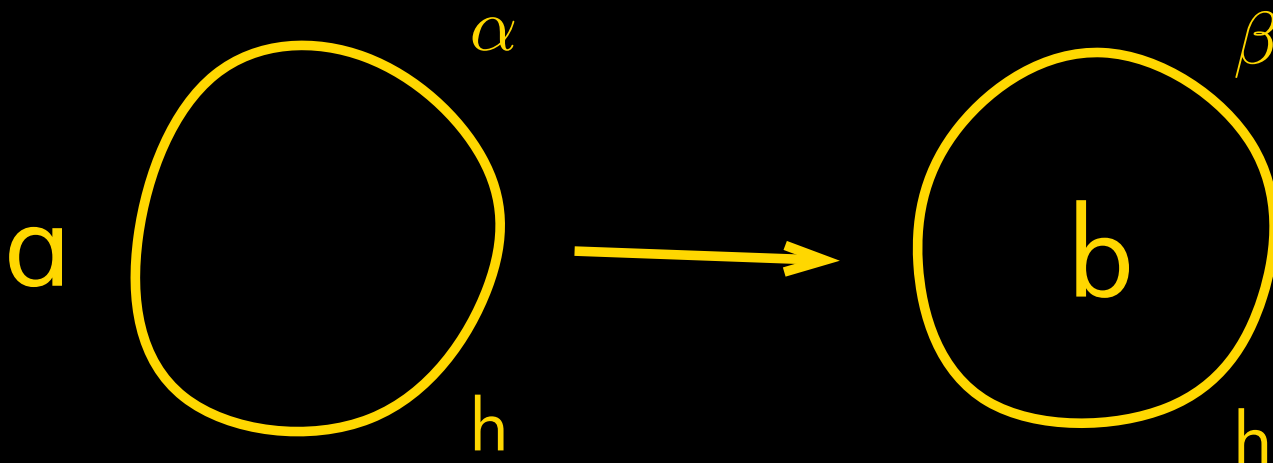
OBJECT EVOLUTION



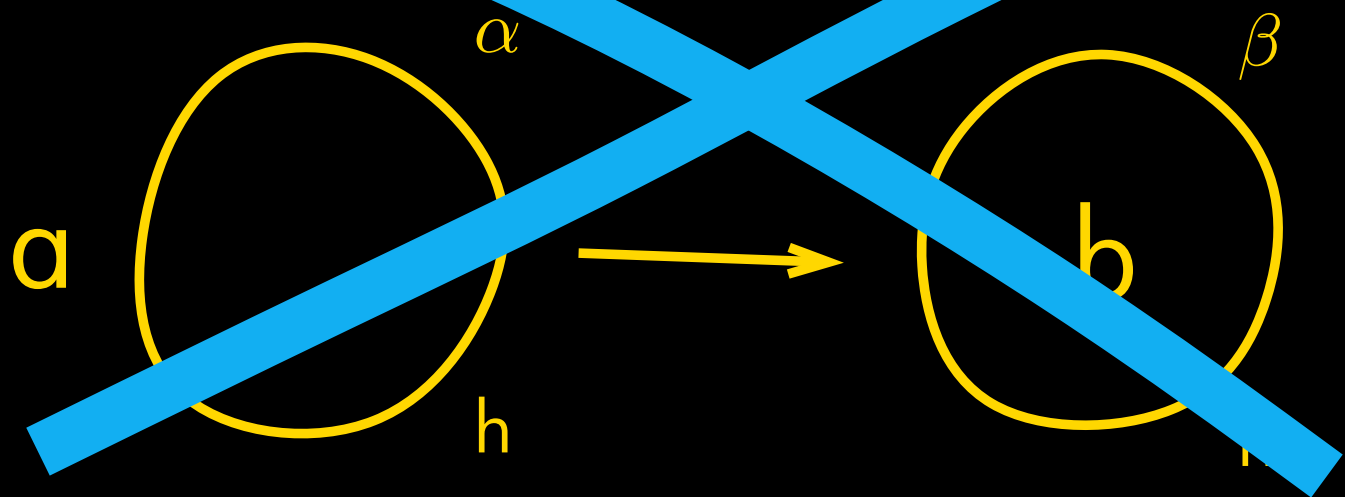
SEND-OUT



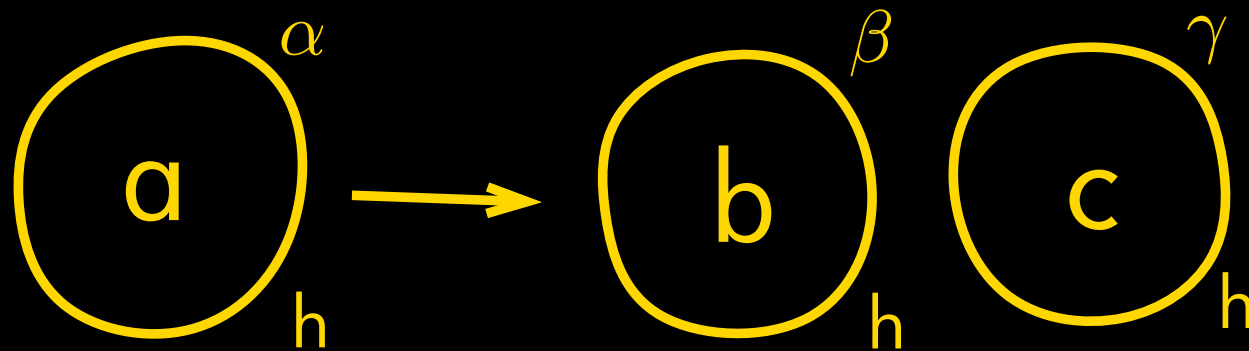
SEND-IN



SEND-IN



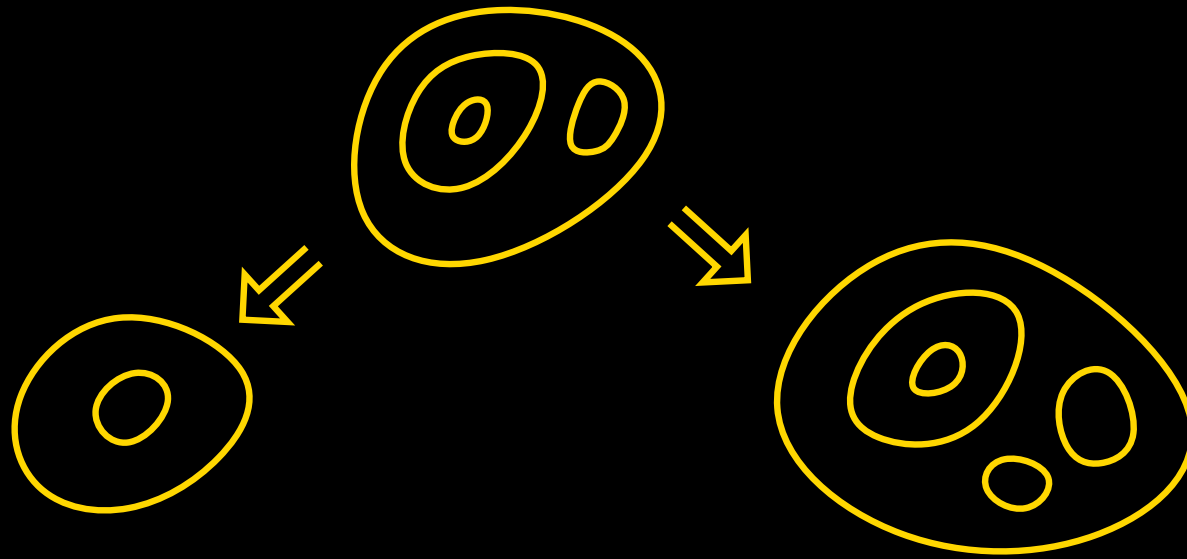
ELEMENTARY DIVISION



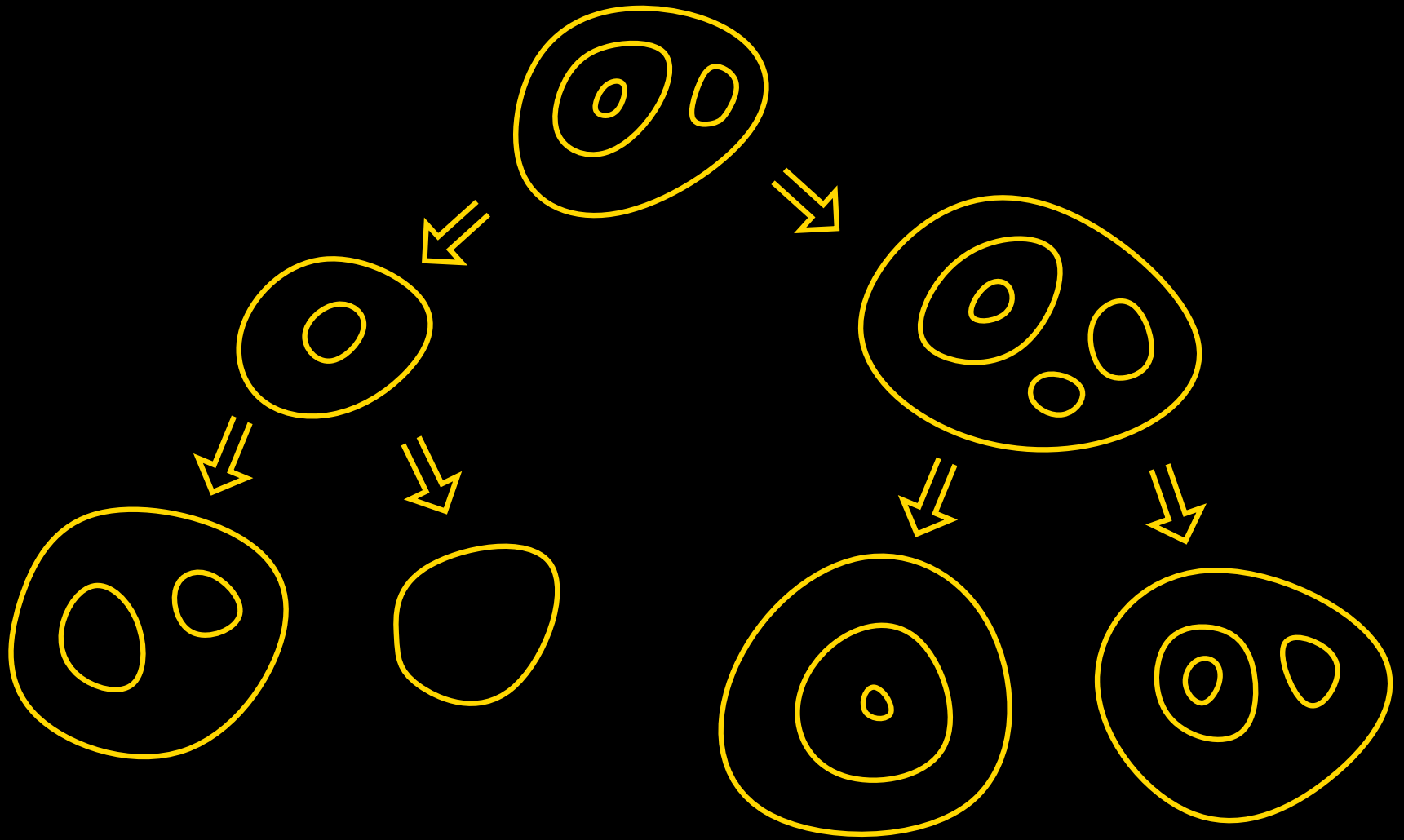
NON-CONFLUENCE



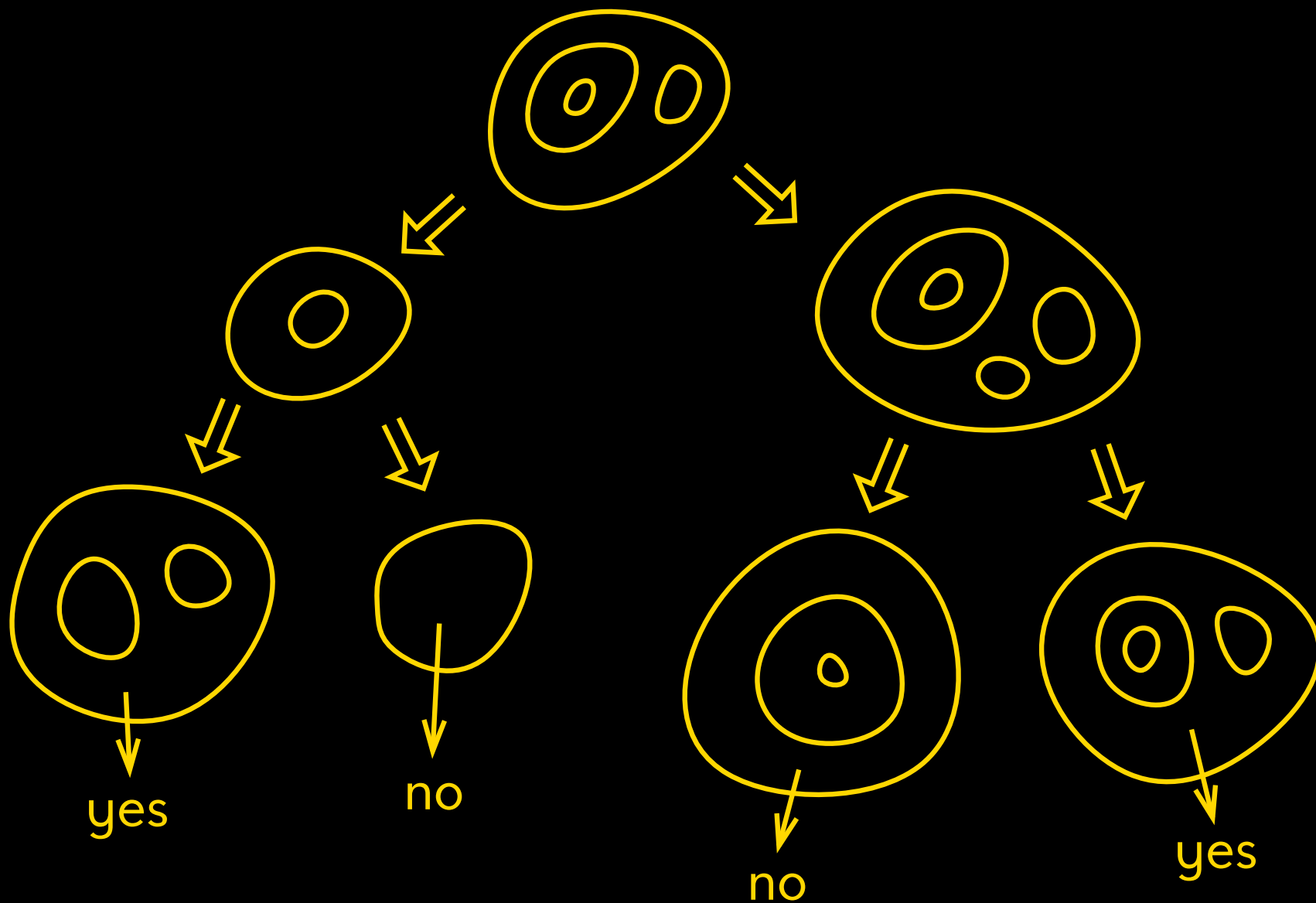
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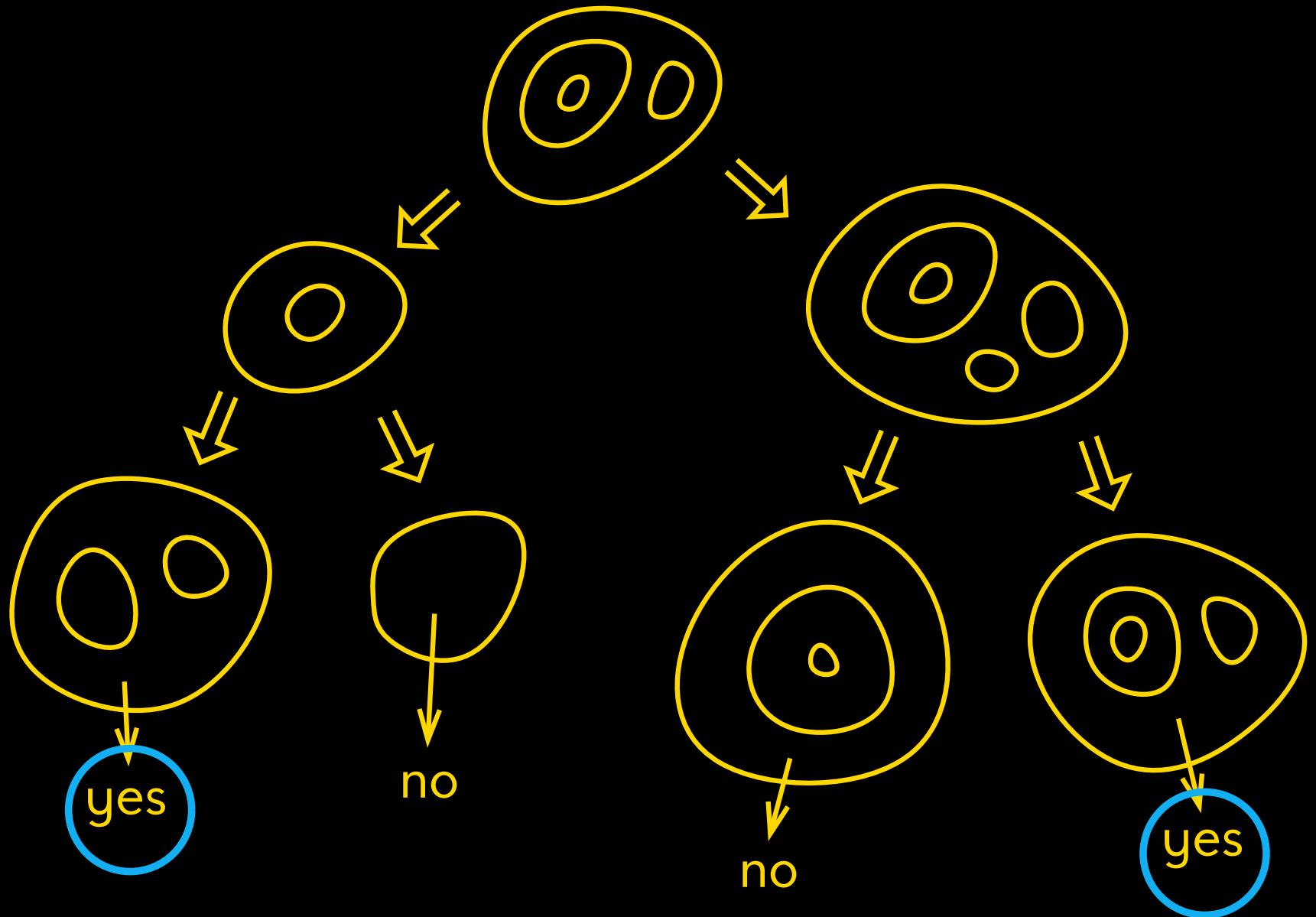
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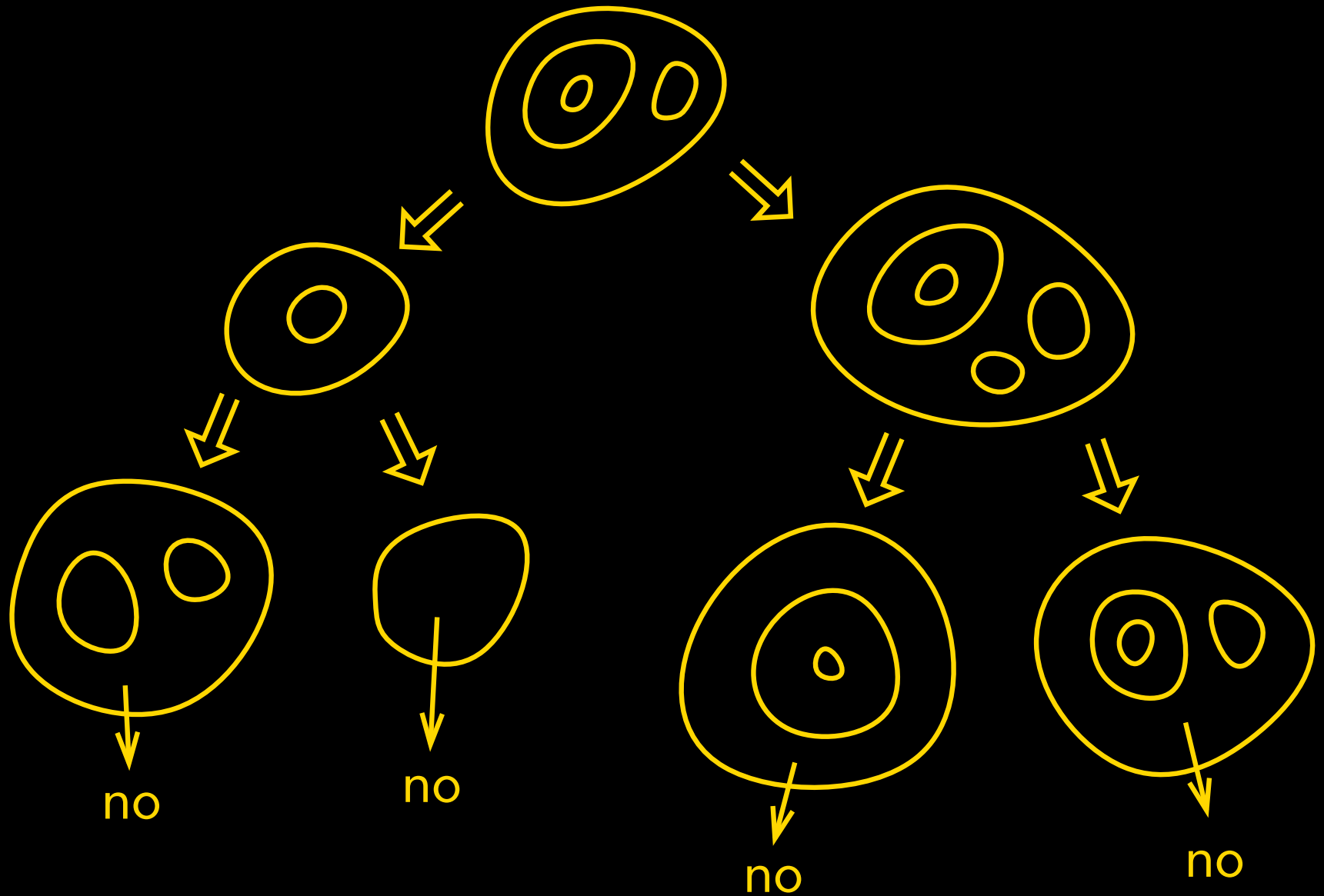
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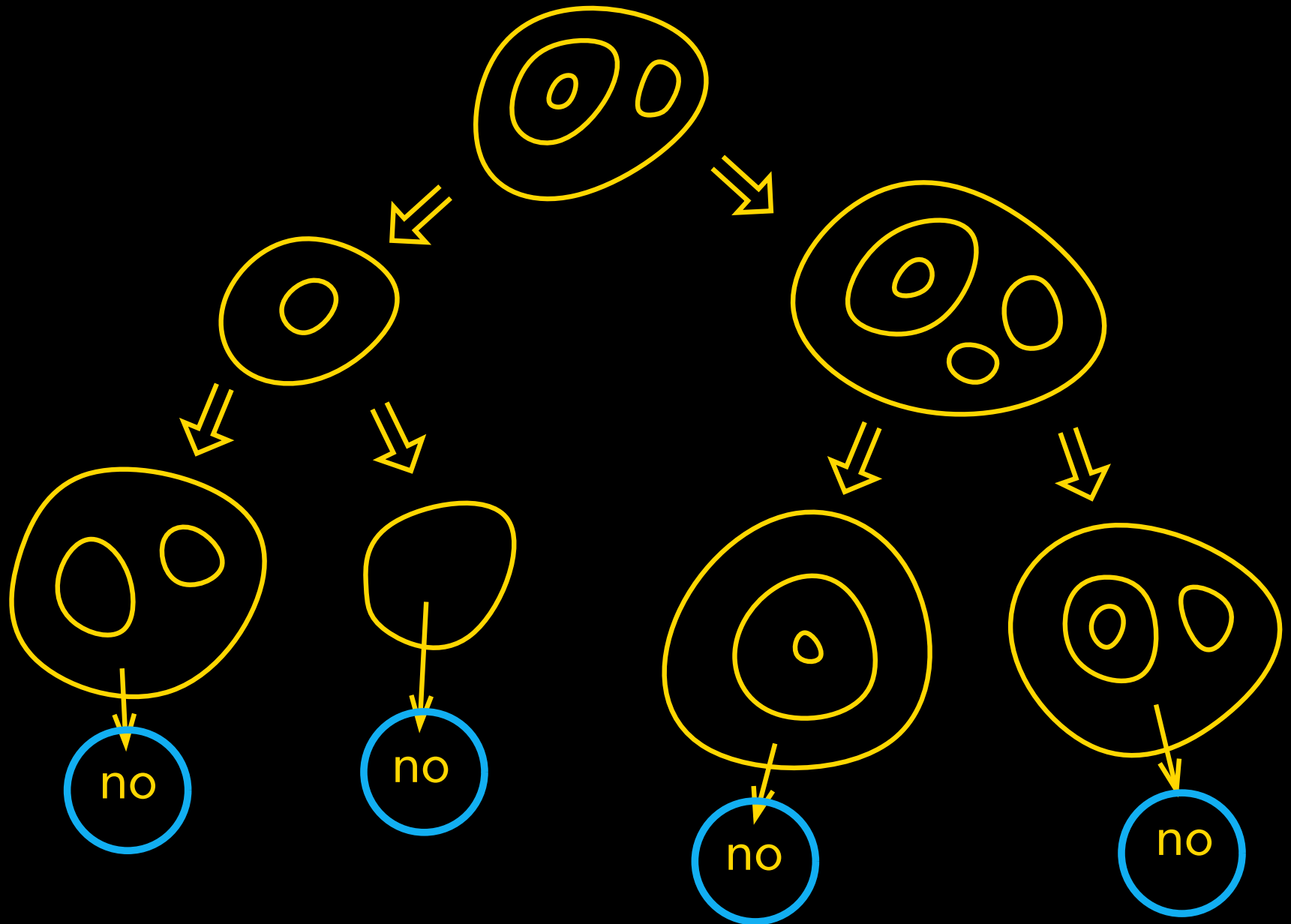
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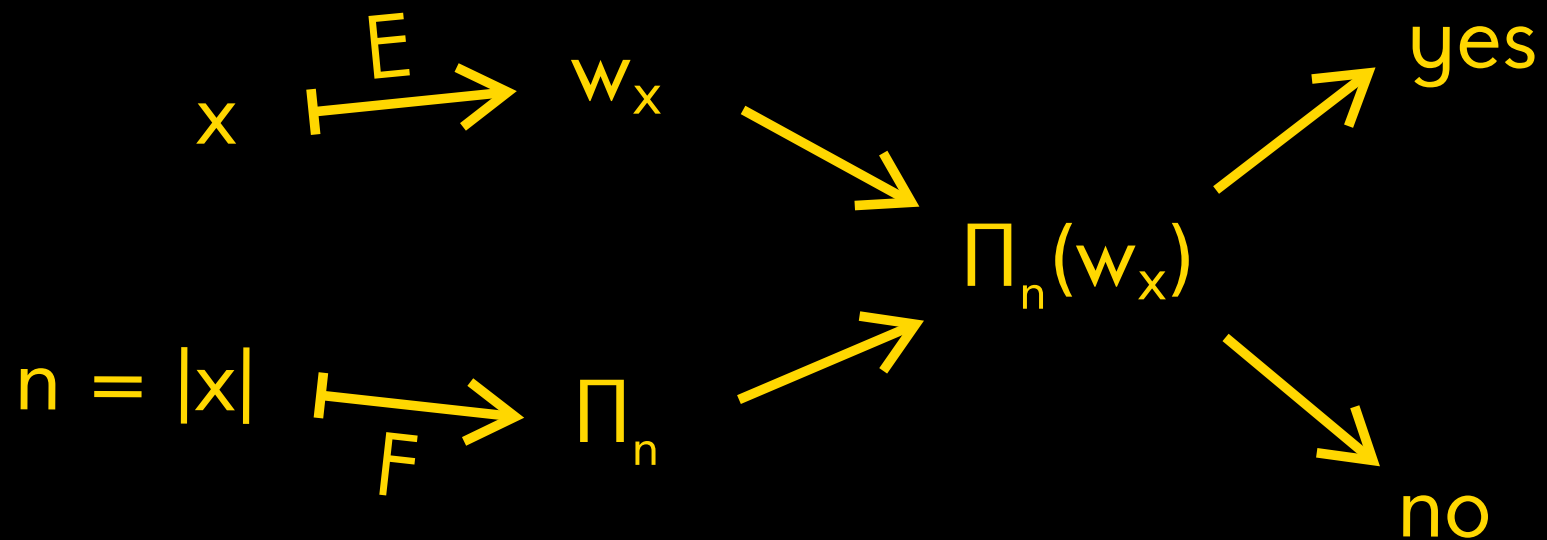
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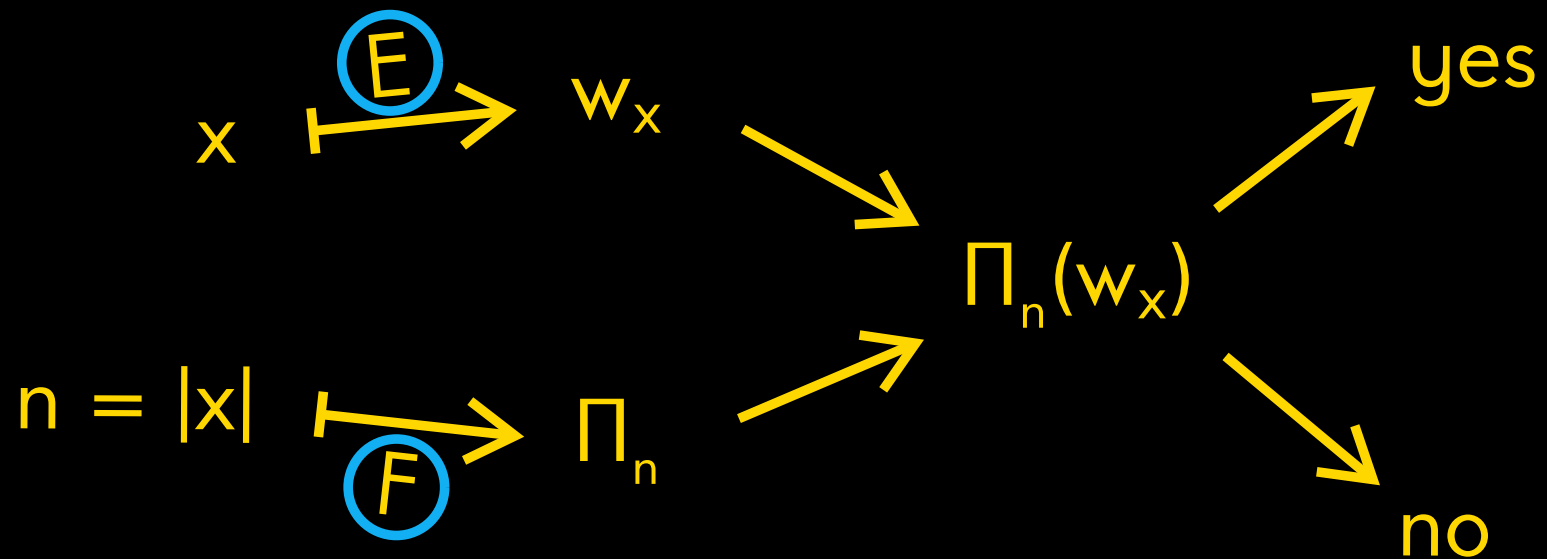
NON-CONFLUENCE



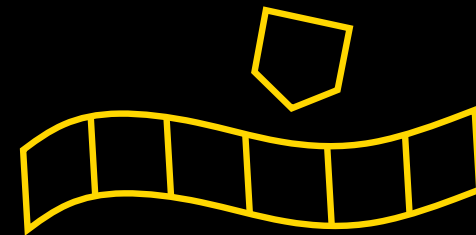
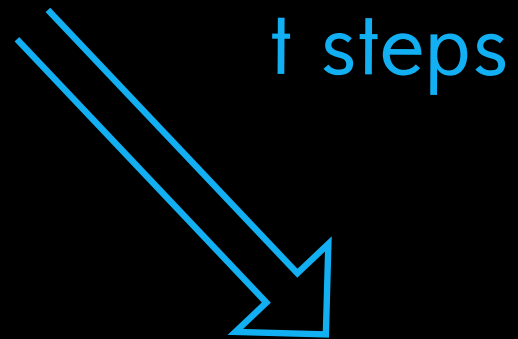
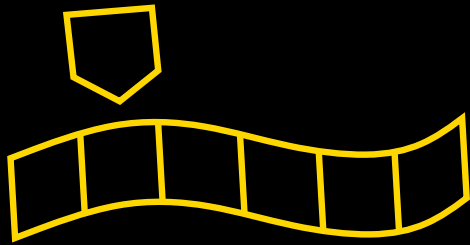
UNIFORM FAMILY Π



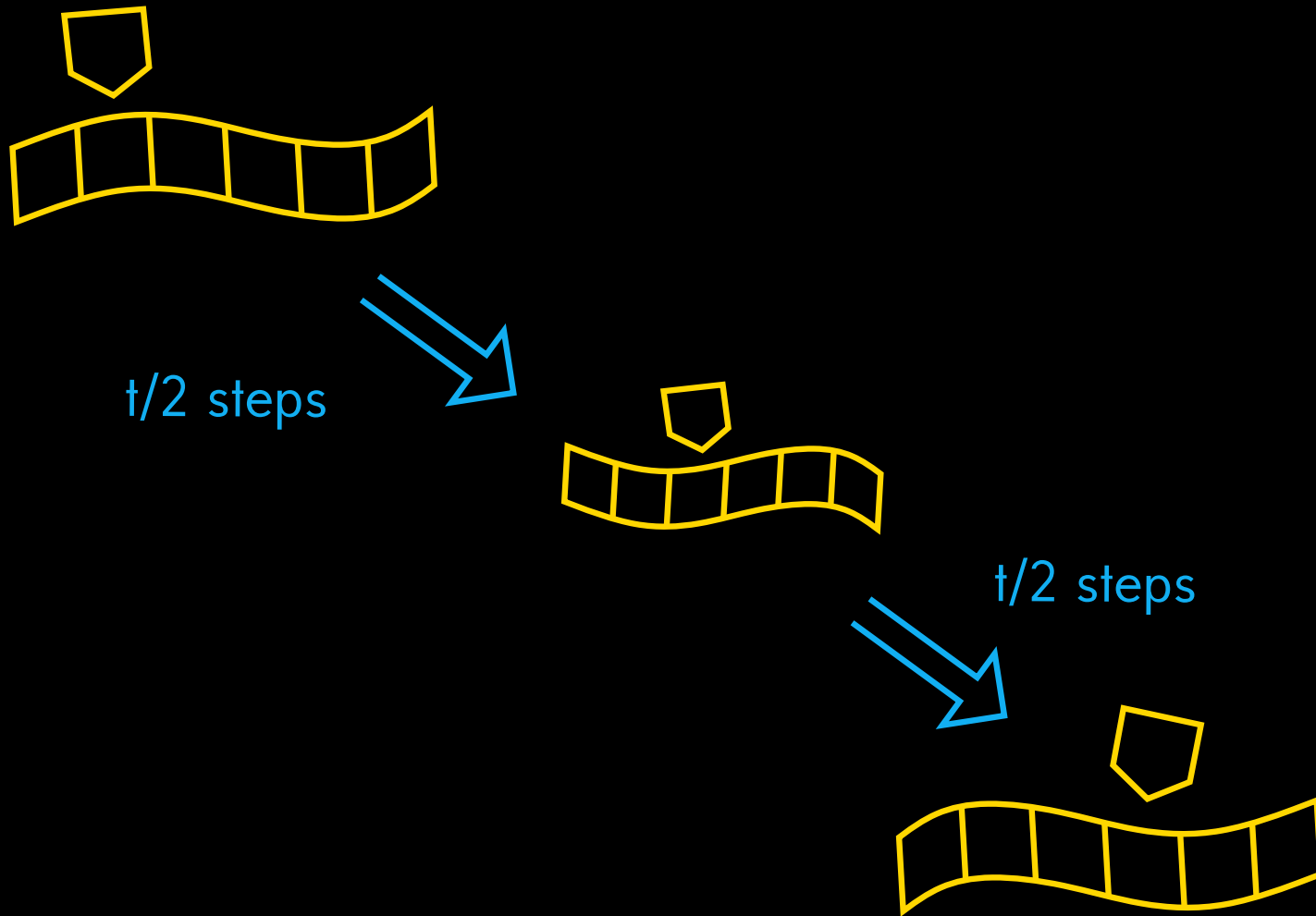
UNIFORM FAMILY Π



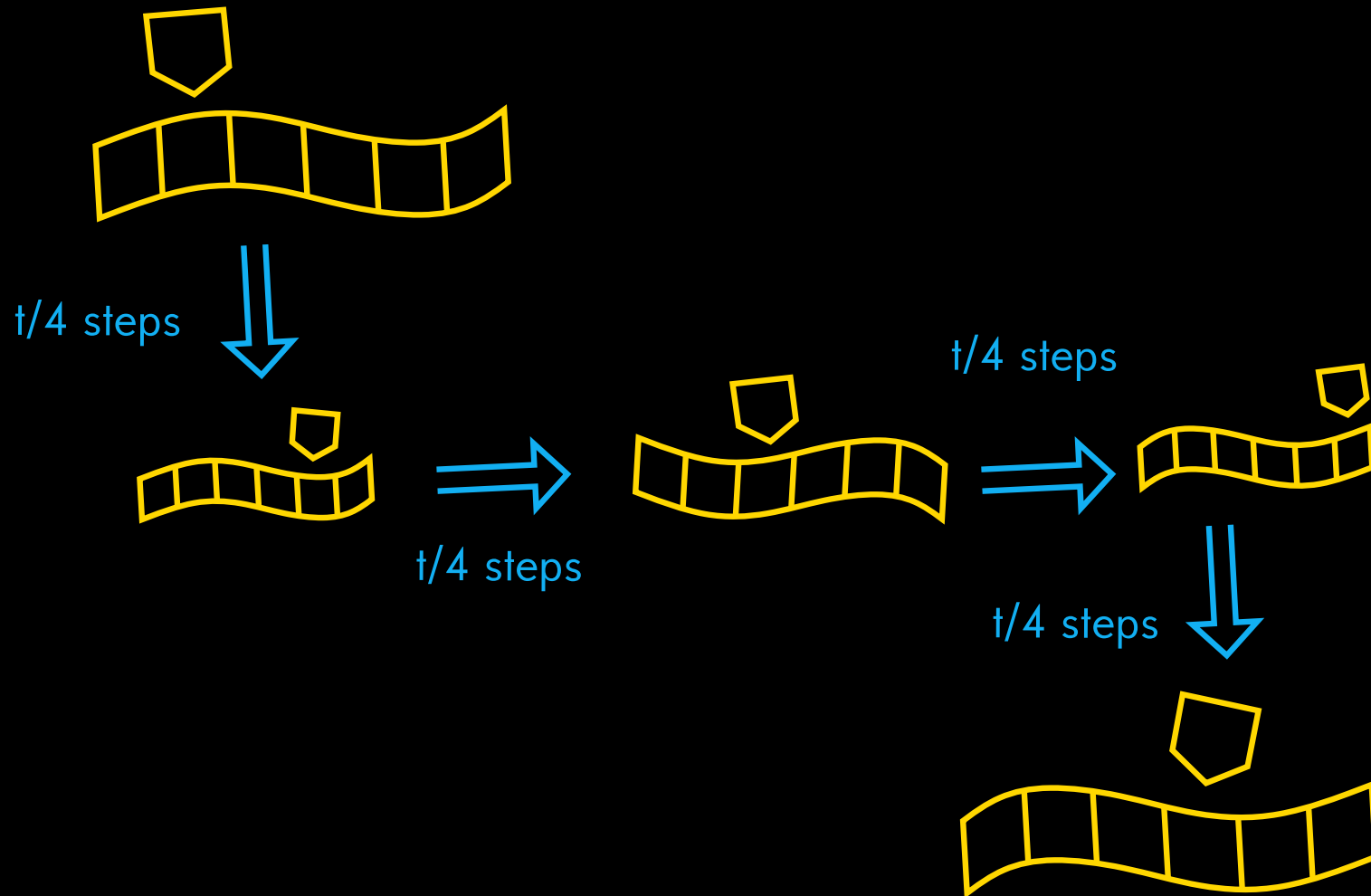
TM COMPUTATIONS



TM COMPUTATIONS



TM COMPUTATIONS



Algorithm 1

SIMULATING PSPACE TMs

Given configurations C_i and C_j of a TM

- if $i = j$ then ACCEPT
- if $i + 1 = j$ then CHECK if $C_i \rightarrow C_j$
- else GUESS midpoint and go on in parallel

non-confluence!

membrane
division!

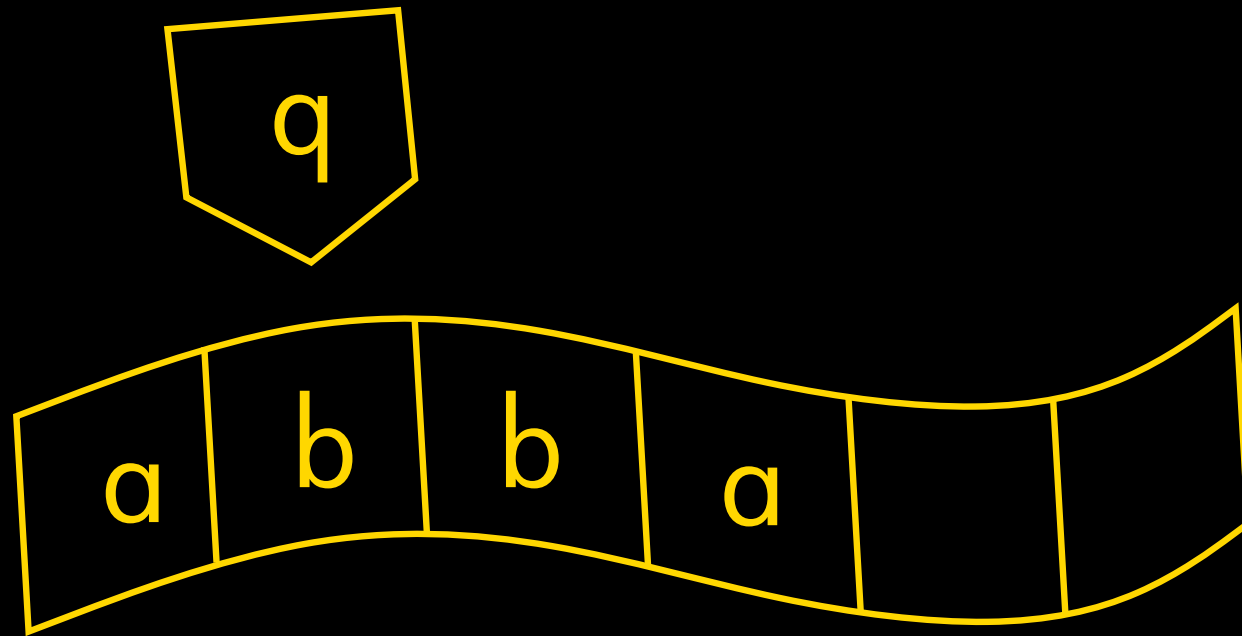
Algorithm 1

SIMULATING PSPACE TMs

Given configurations C_i and C_j of a TM

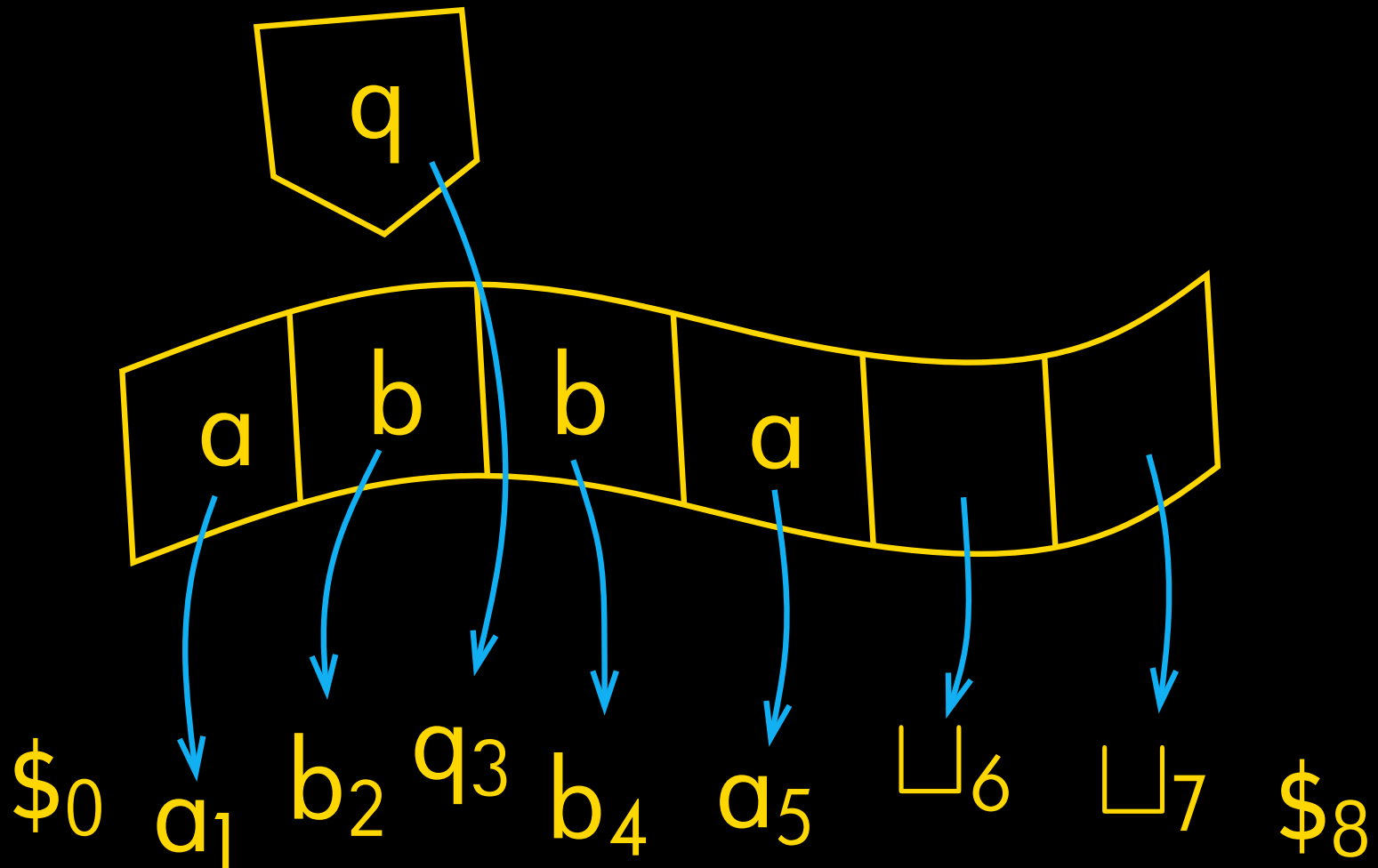
- if $i = j$ then ACCEPT
- if $i + 1 = j$ then CHECK if $C_i \rightarrow C_j$
- else **GUESS** midpoint and go on in **parallel**

ENCODING TM CFGs

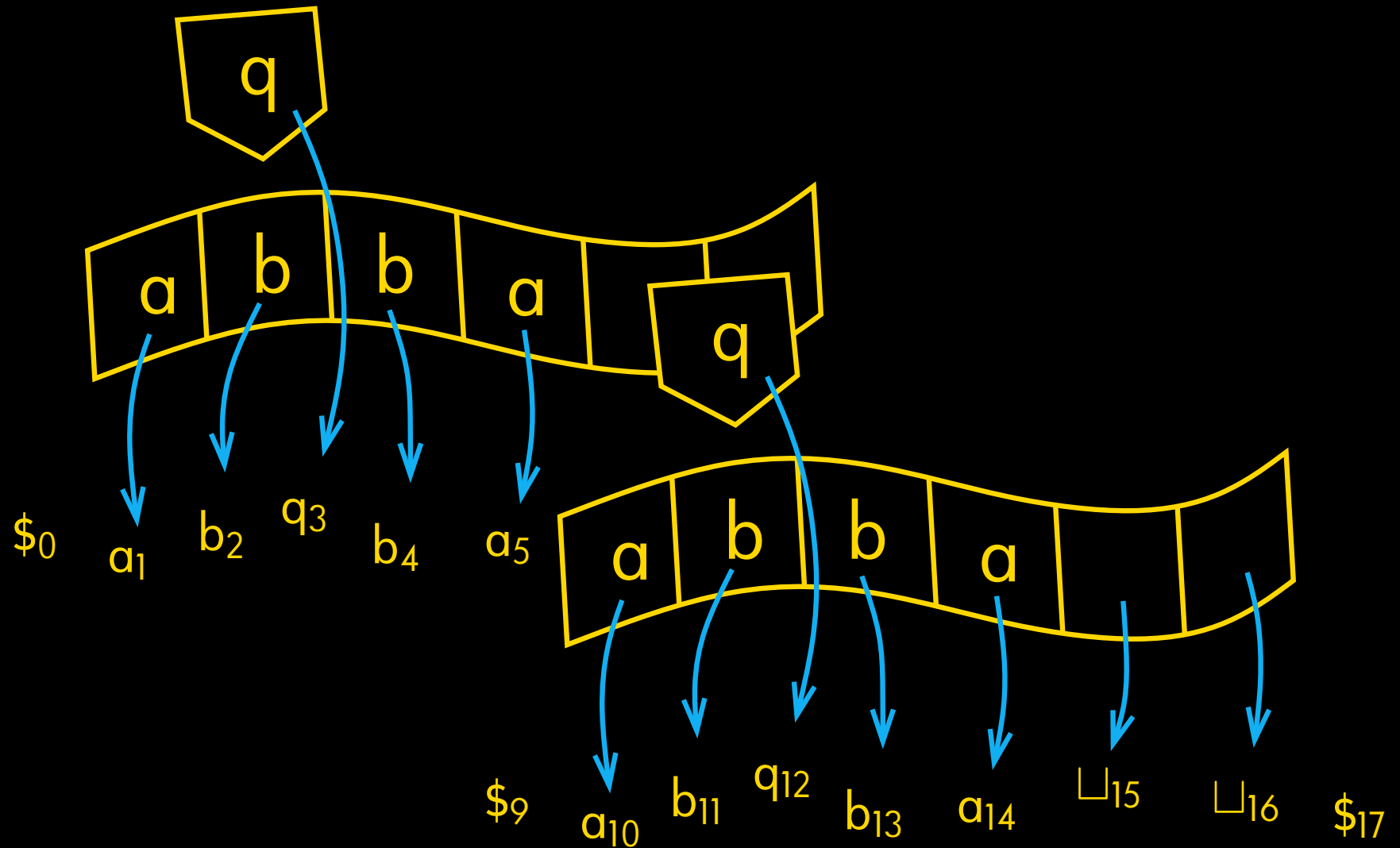


$\$0$ a_1 b_2 q_3 b_4 a_5 \sqcup_6 \sqcup_7 $\$8$

ENCODING TM CFGs

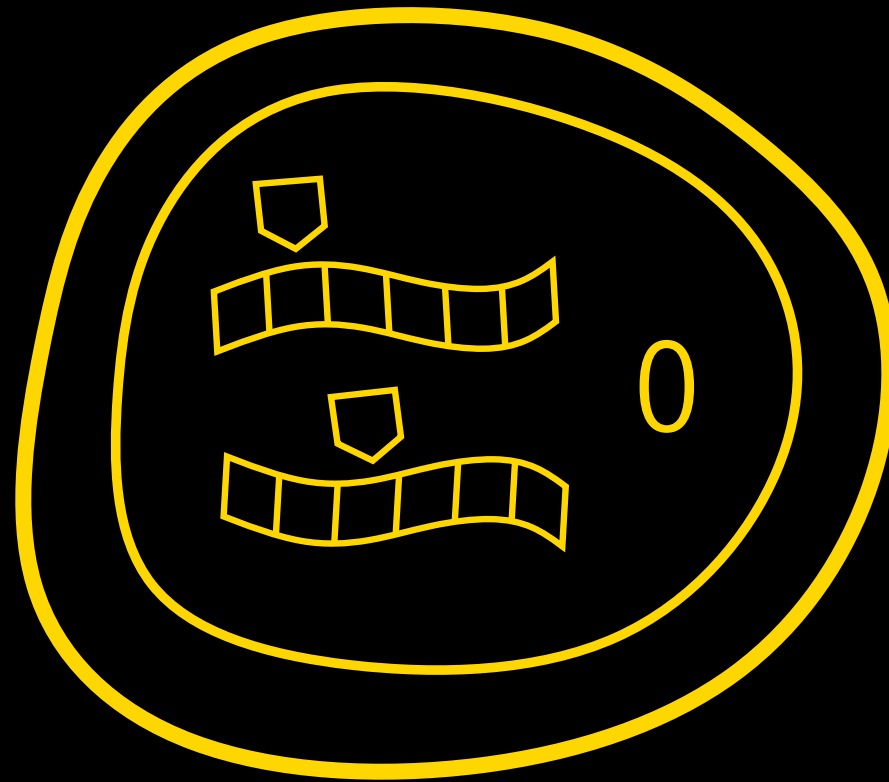


ENCODING TWO TM CFGs



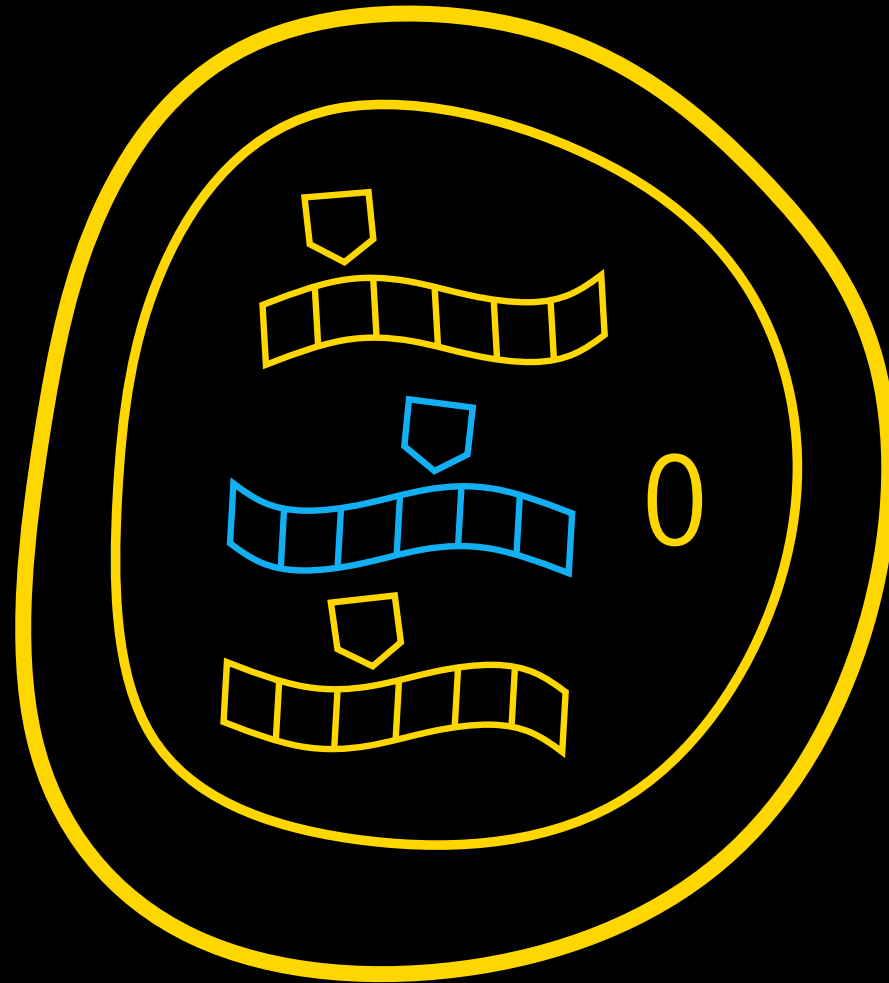
Algorithm 1

IMPLEMENTATION



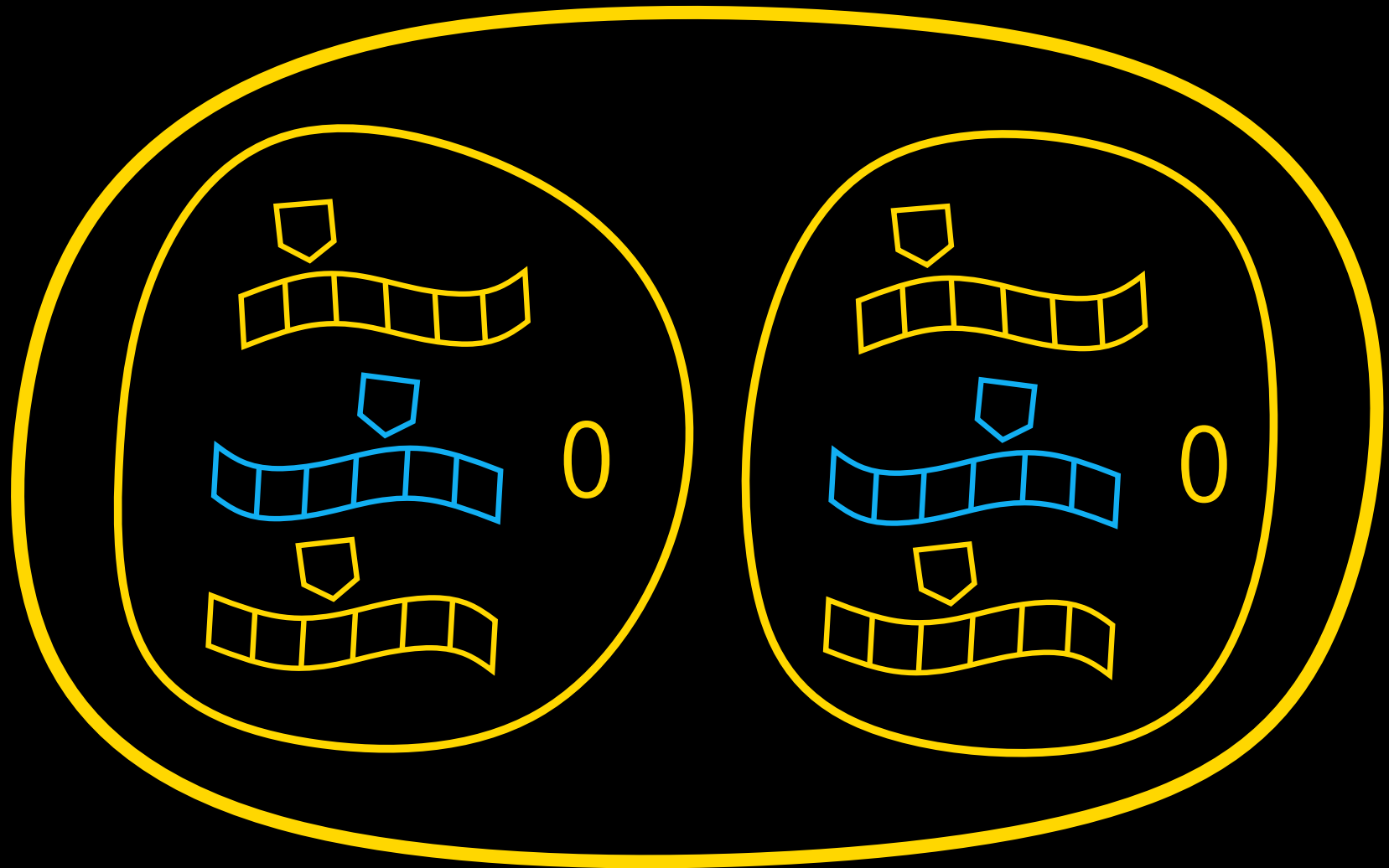
Algorithm 1

IMPLEMENTATION



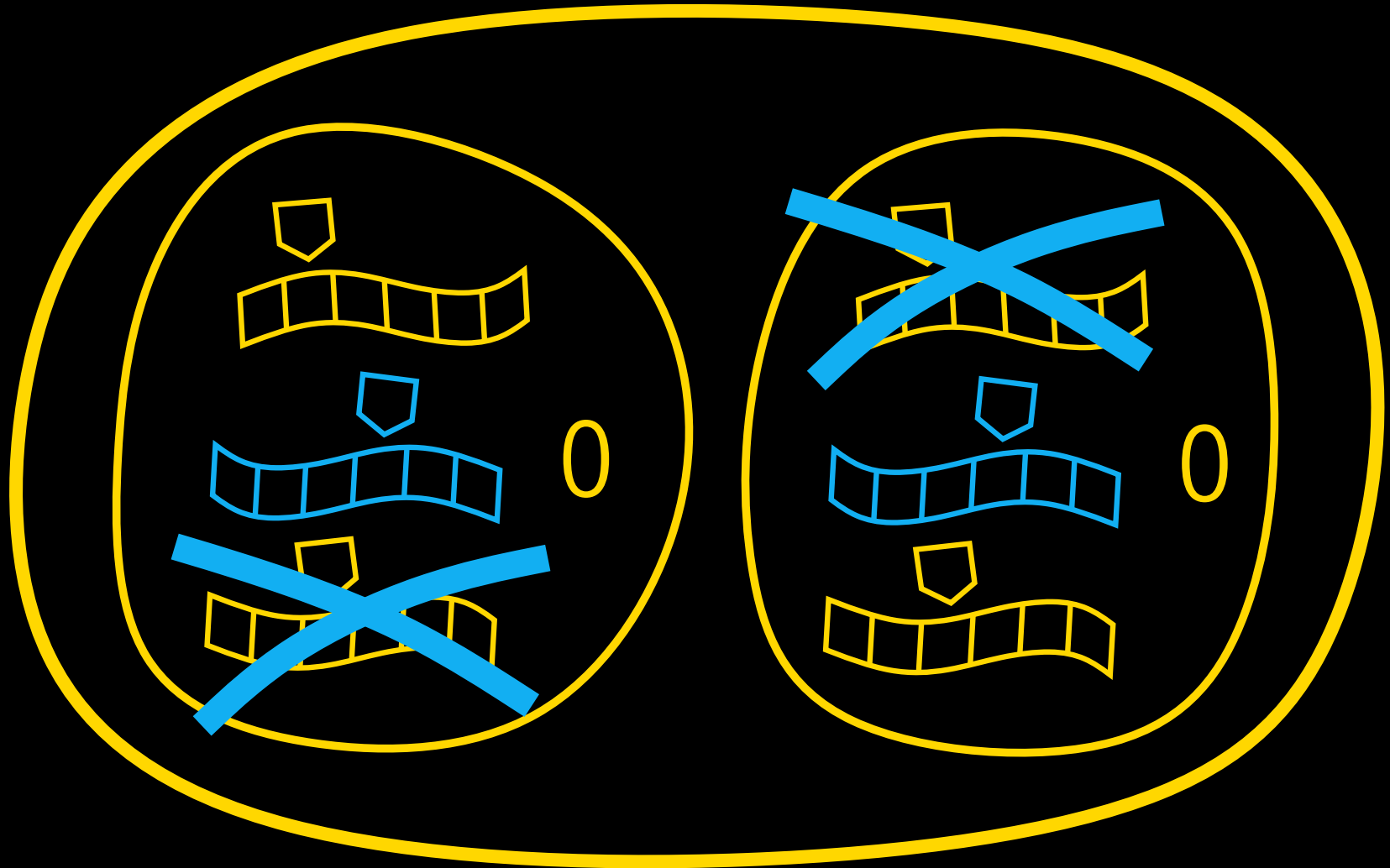
Algorithm 1

IMPLEMENTATION



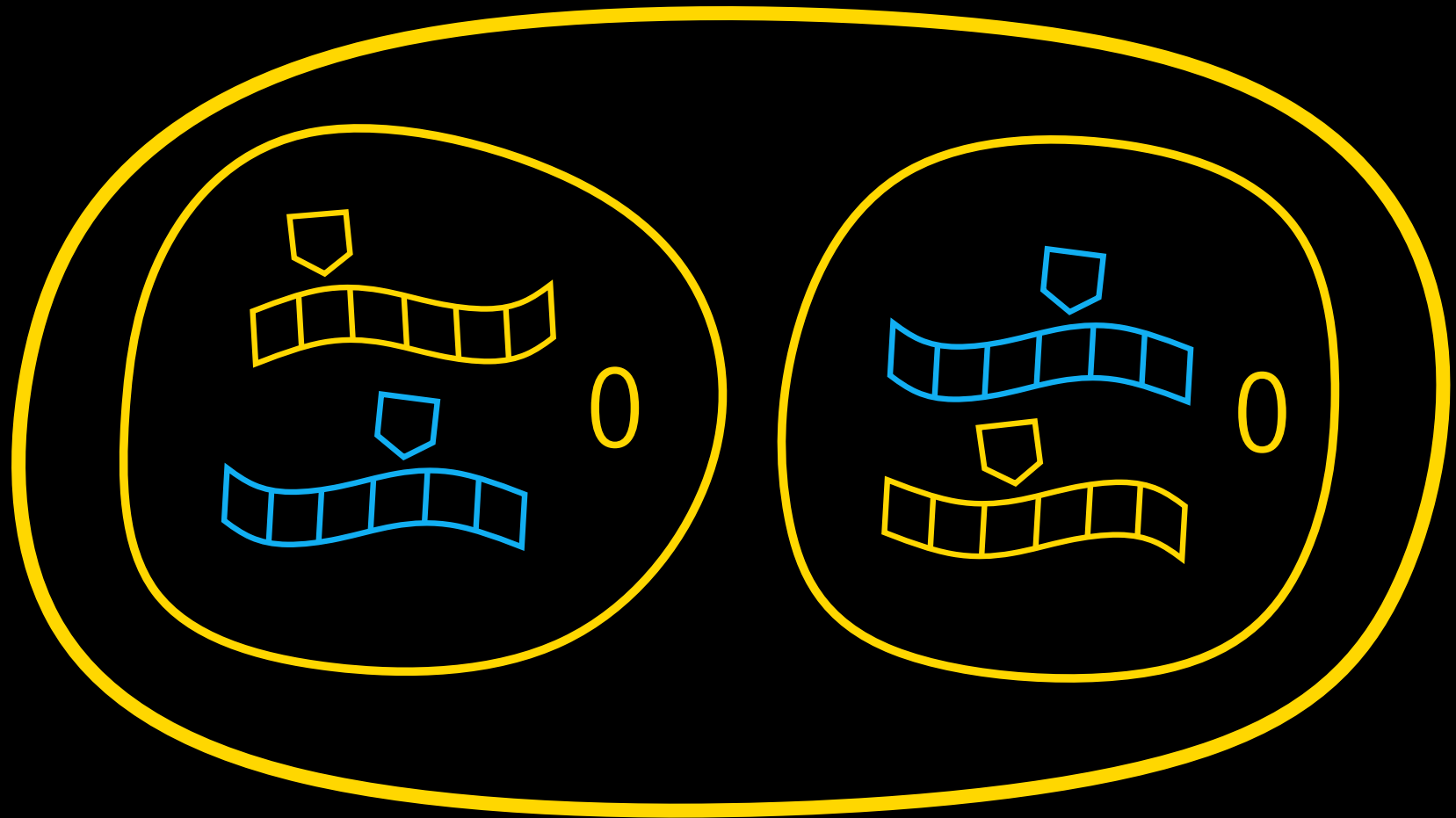
Algorithm 1

IMPLEMENTATION



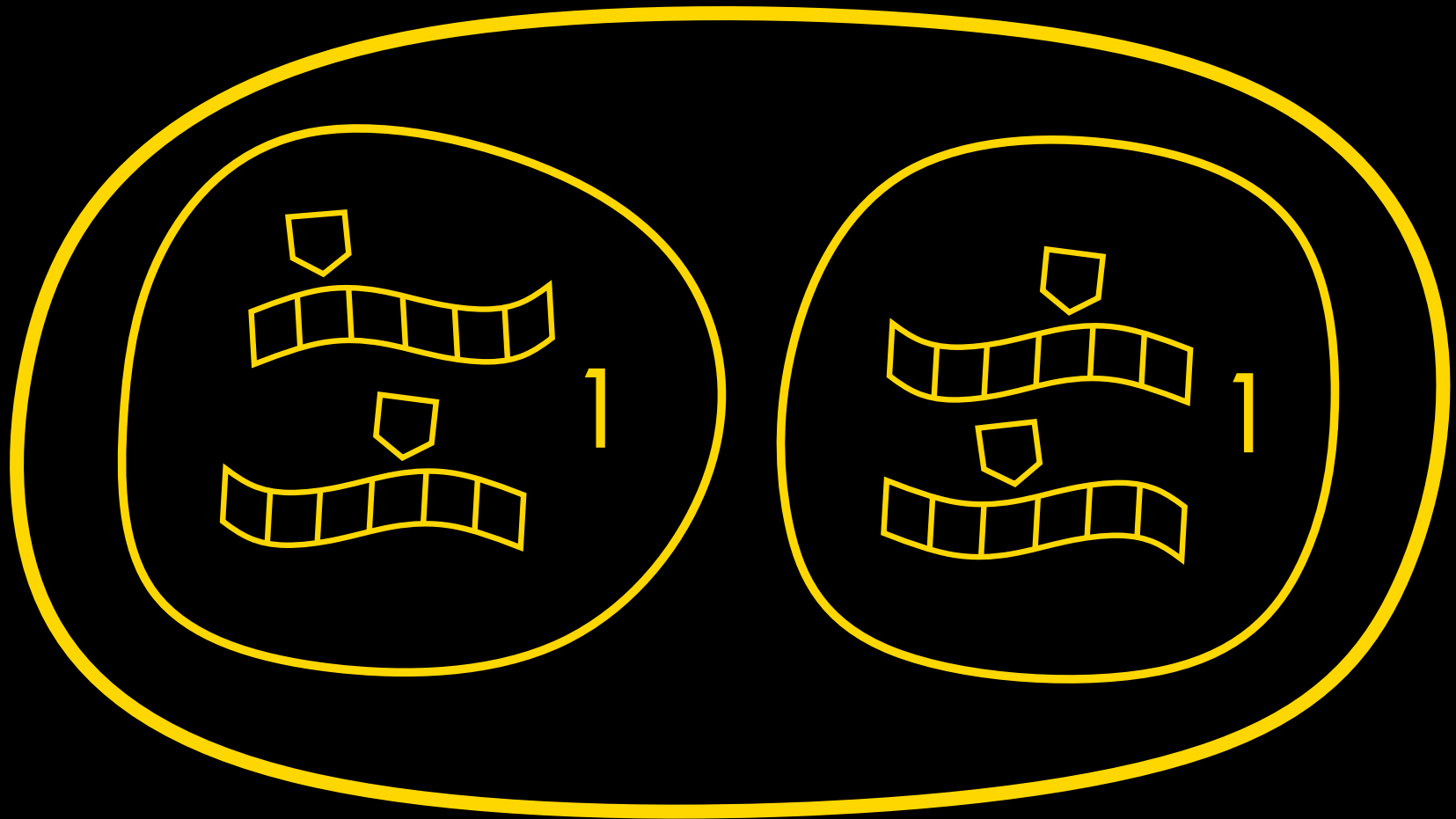
Algorithm 1

IMPLEMENTATION



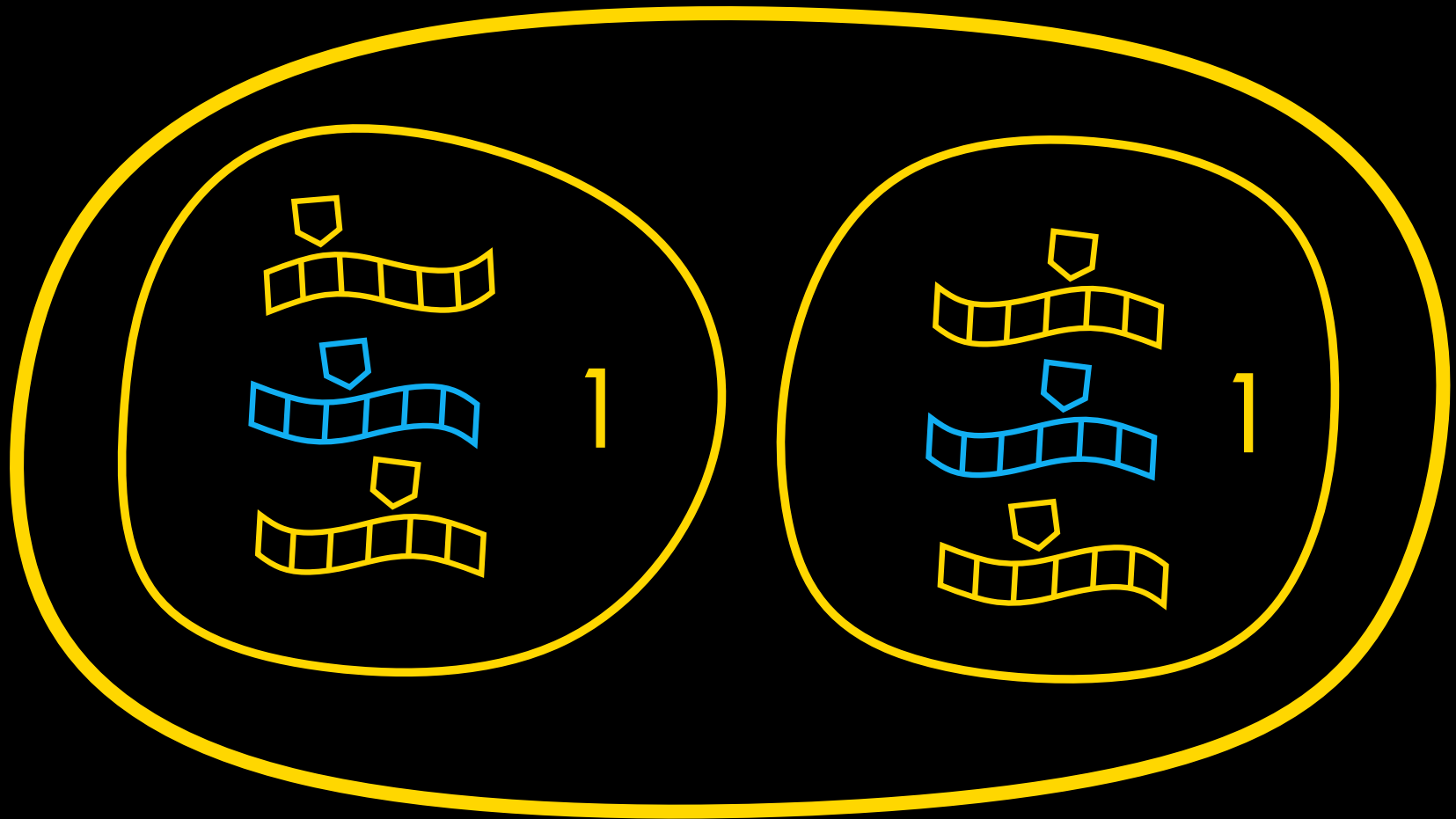
Algorithm 1

IMPLEMENTATION



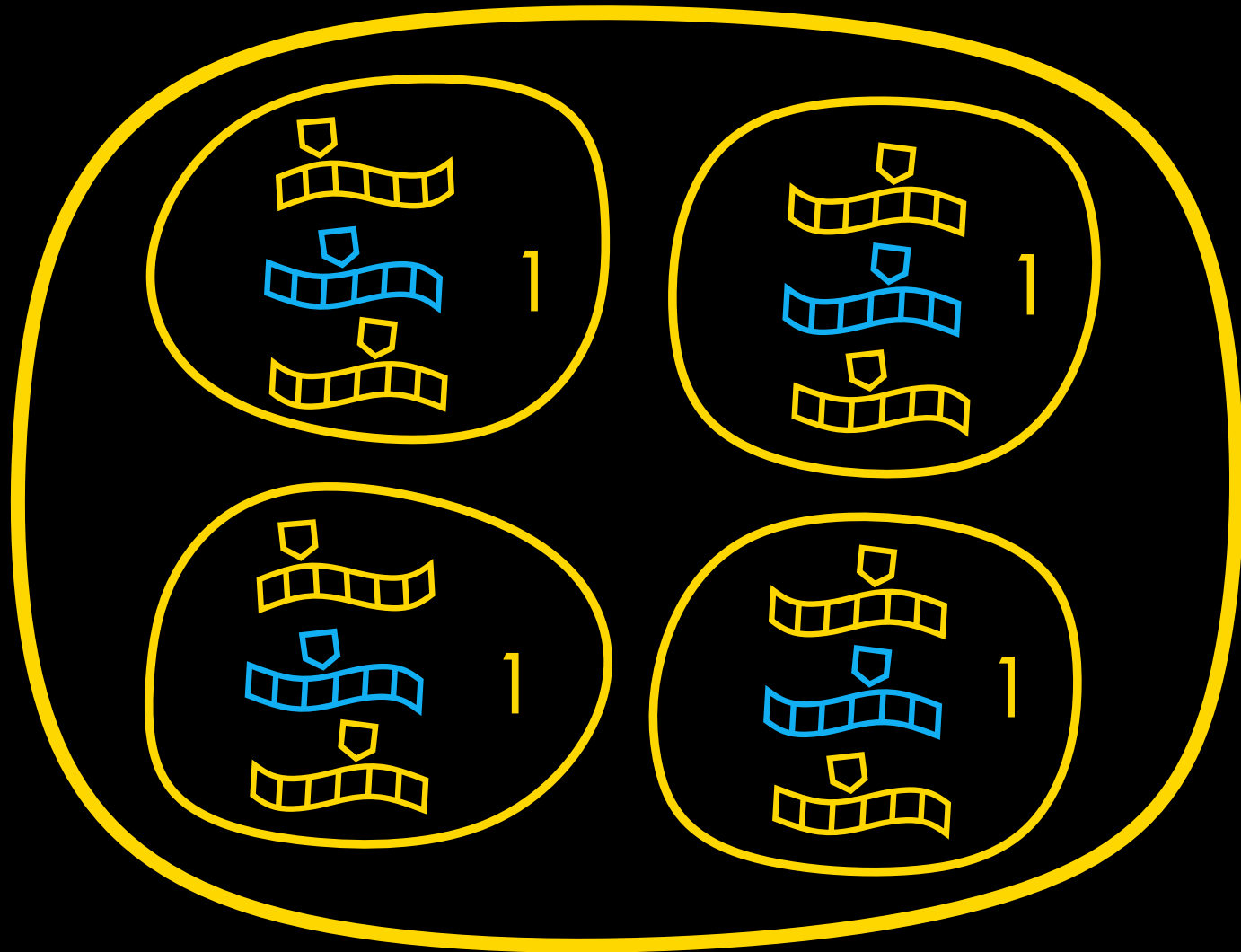
Algorithm 1

IMPLEMENTATION



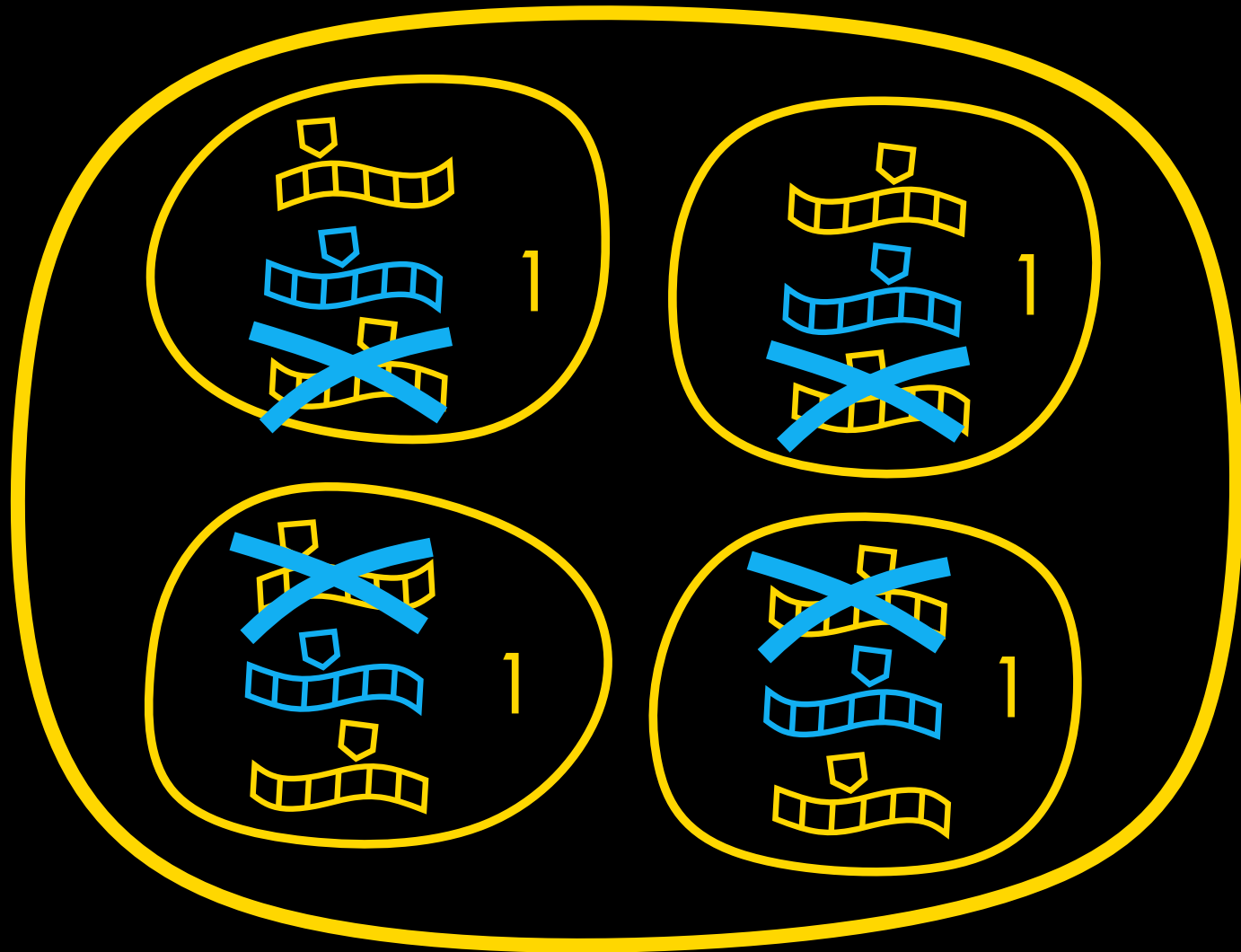
Algorithm 1

IMPLEMENTATION



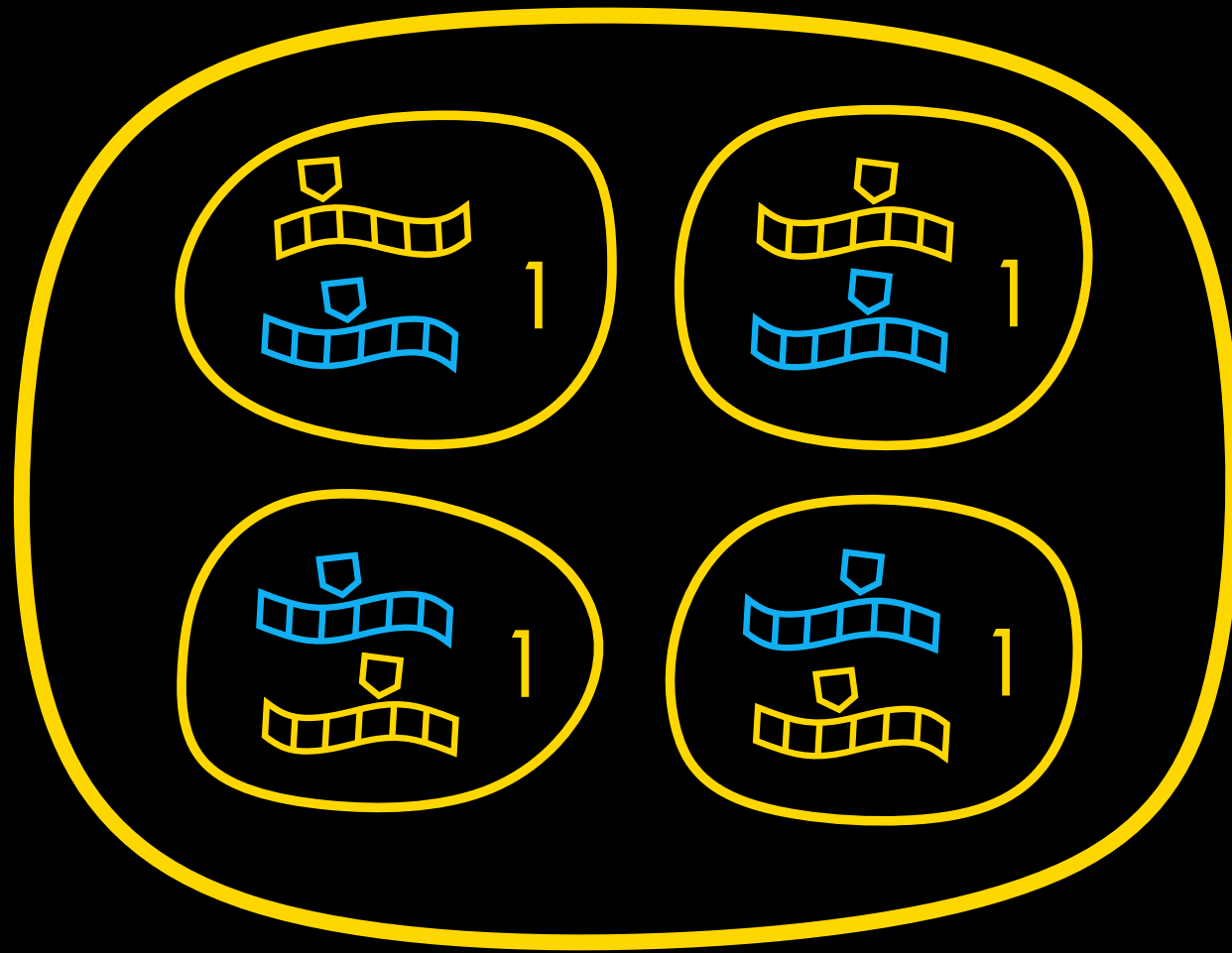
Algorithm 1

IMPLEMENTATION



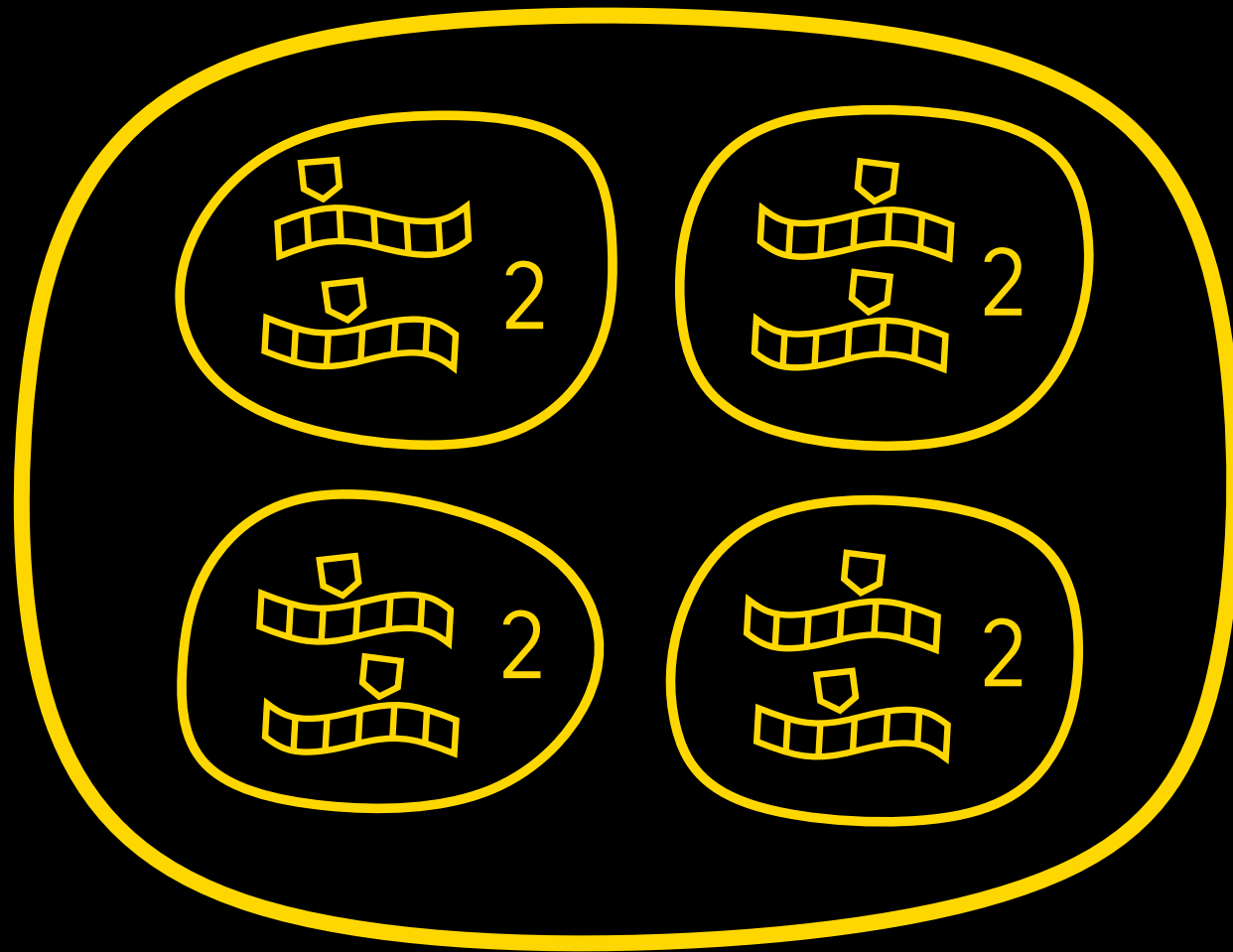
Algorithm 1

IMPLEMENTATION



Algorithm 1

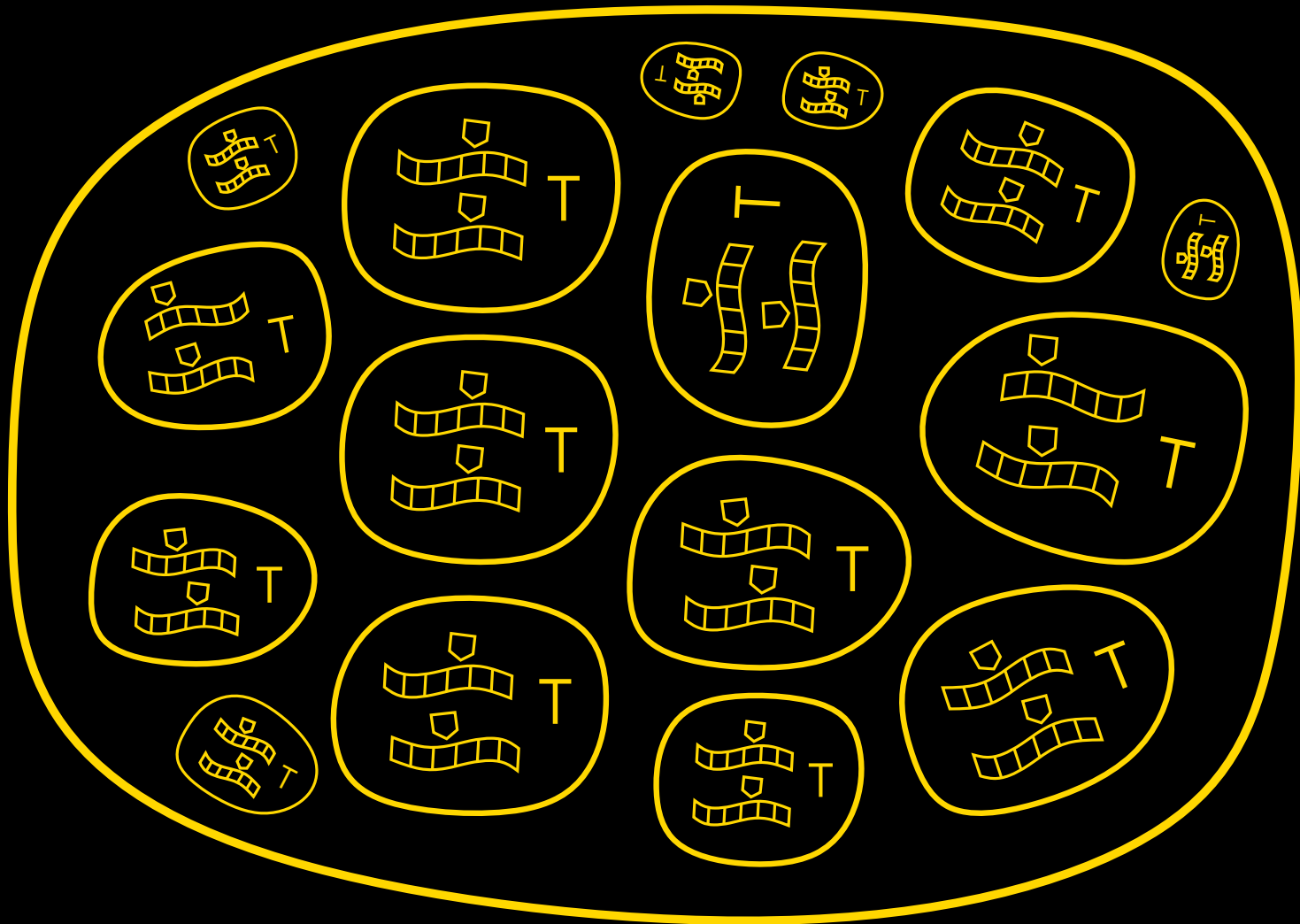
IMPLEMENTATION



After $T = \log(\text{max time})$ many,
many steps....

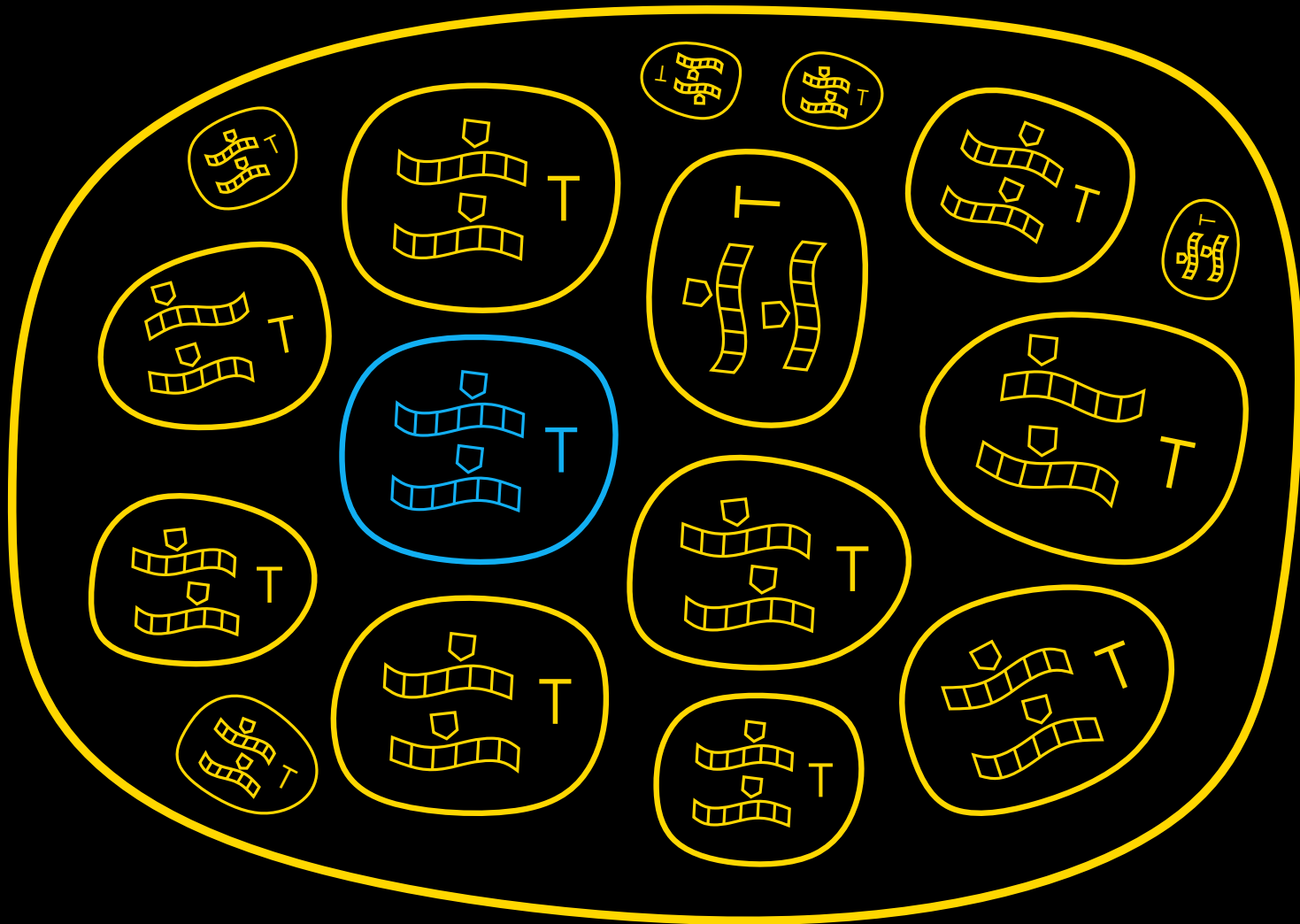
Algorithm I

IMPLEMENTATION



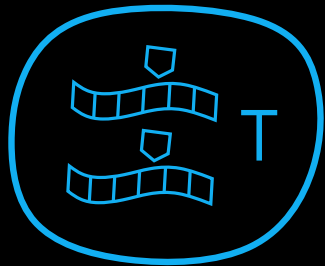
Algorithm I

IMPLEMENTATION



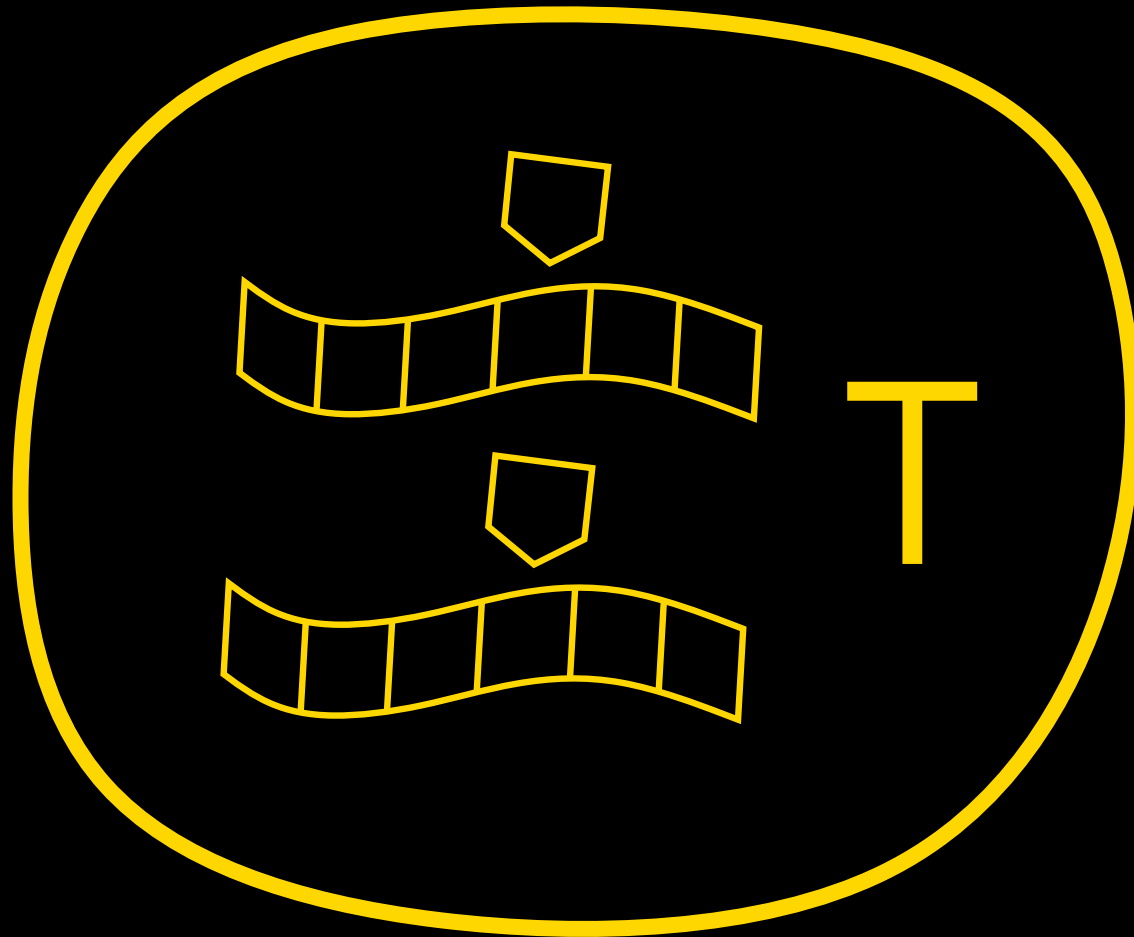
Algorithm 1

IMPLEMENTATION

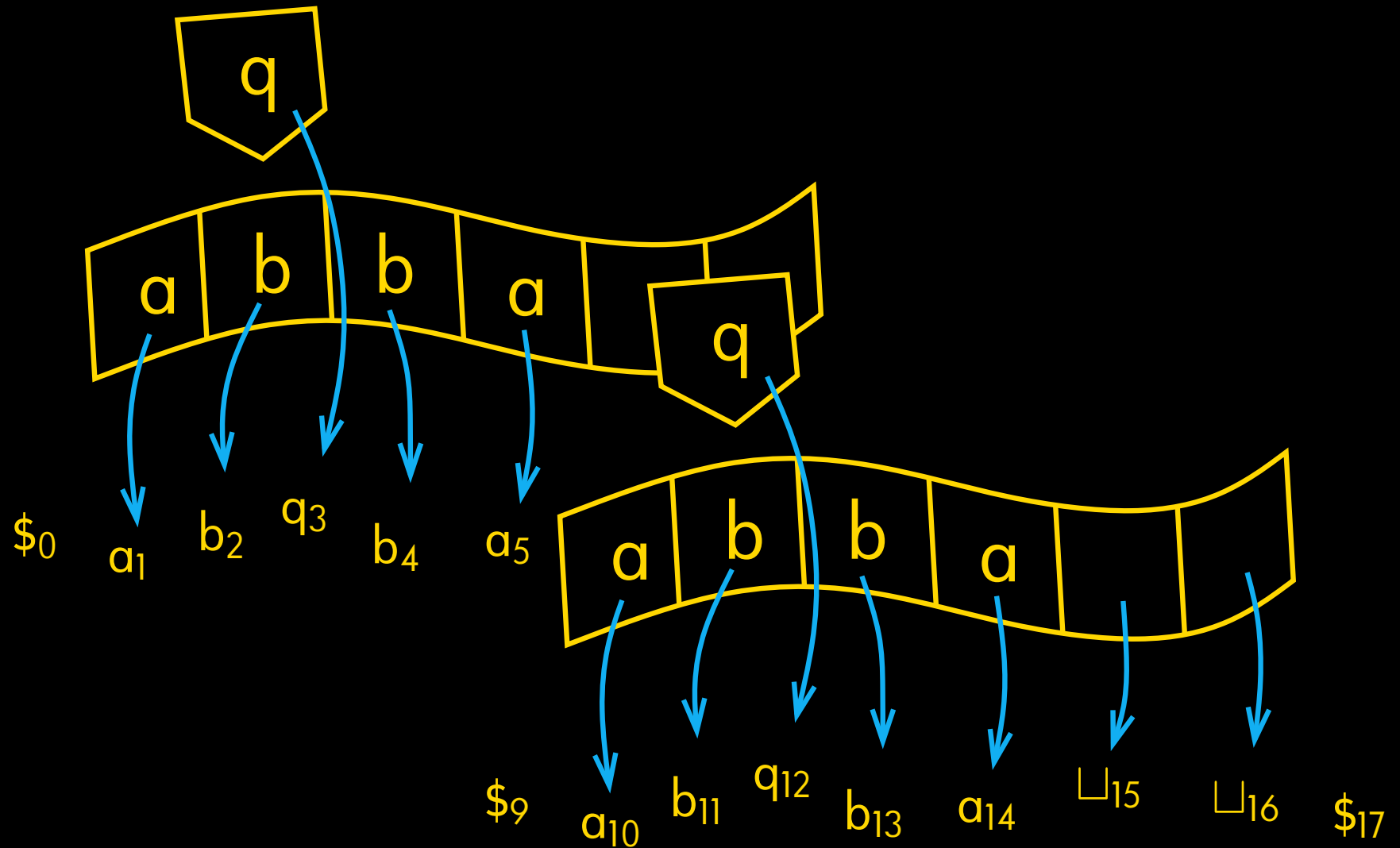


Algorithm 1

IMPLEMENTATION

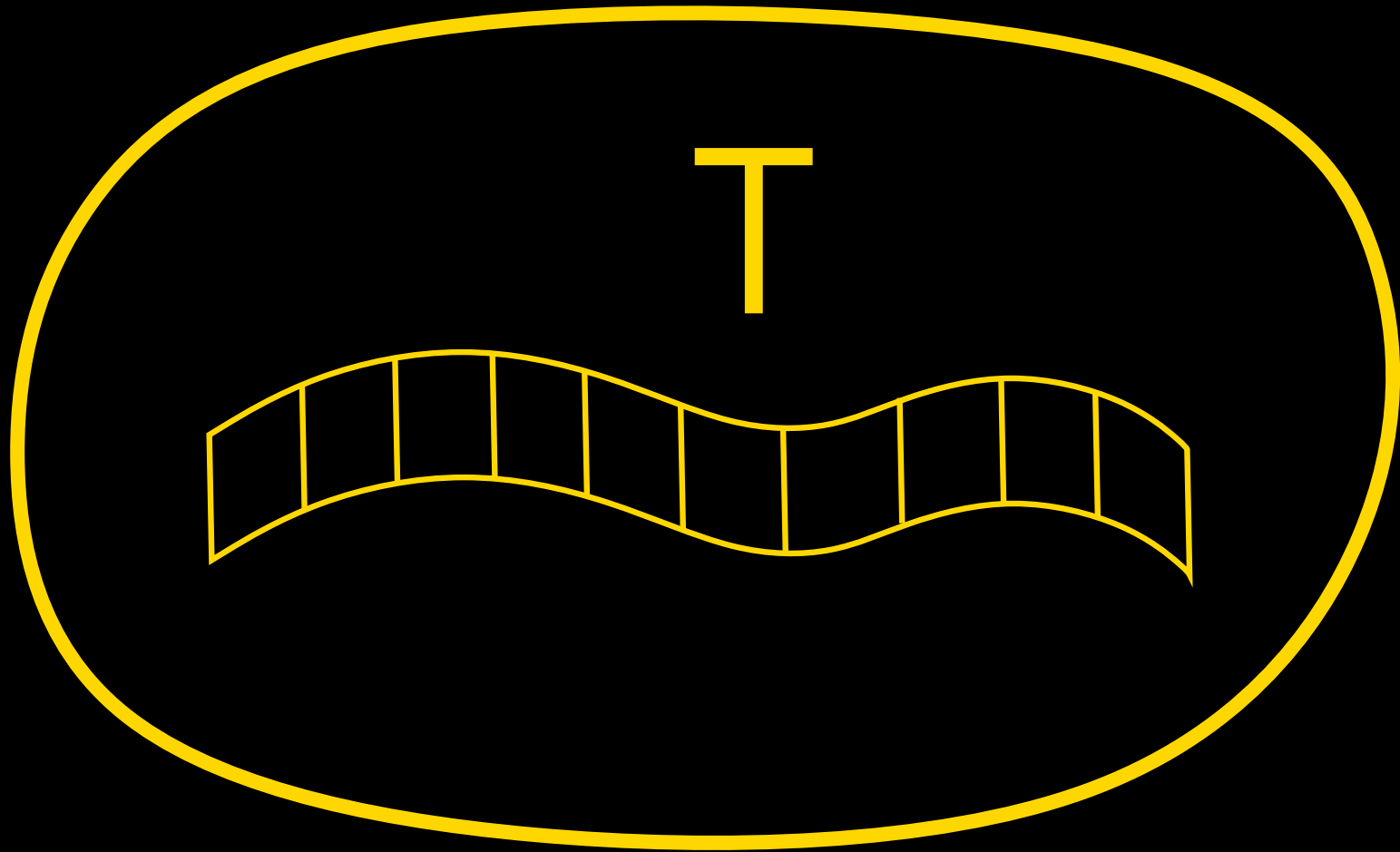


ENCODING TWO TM CFGs



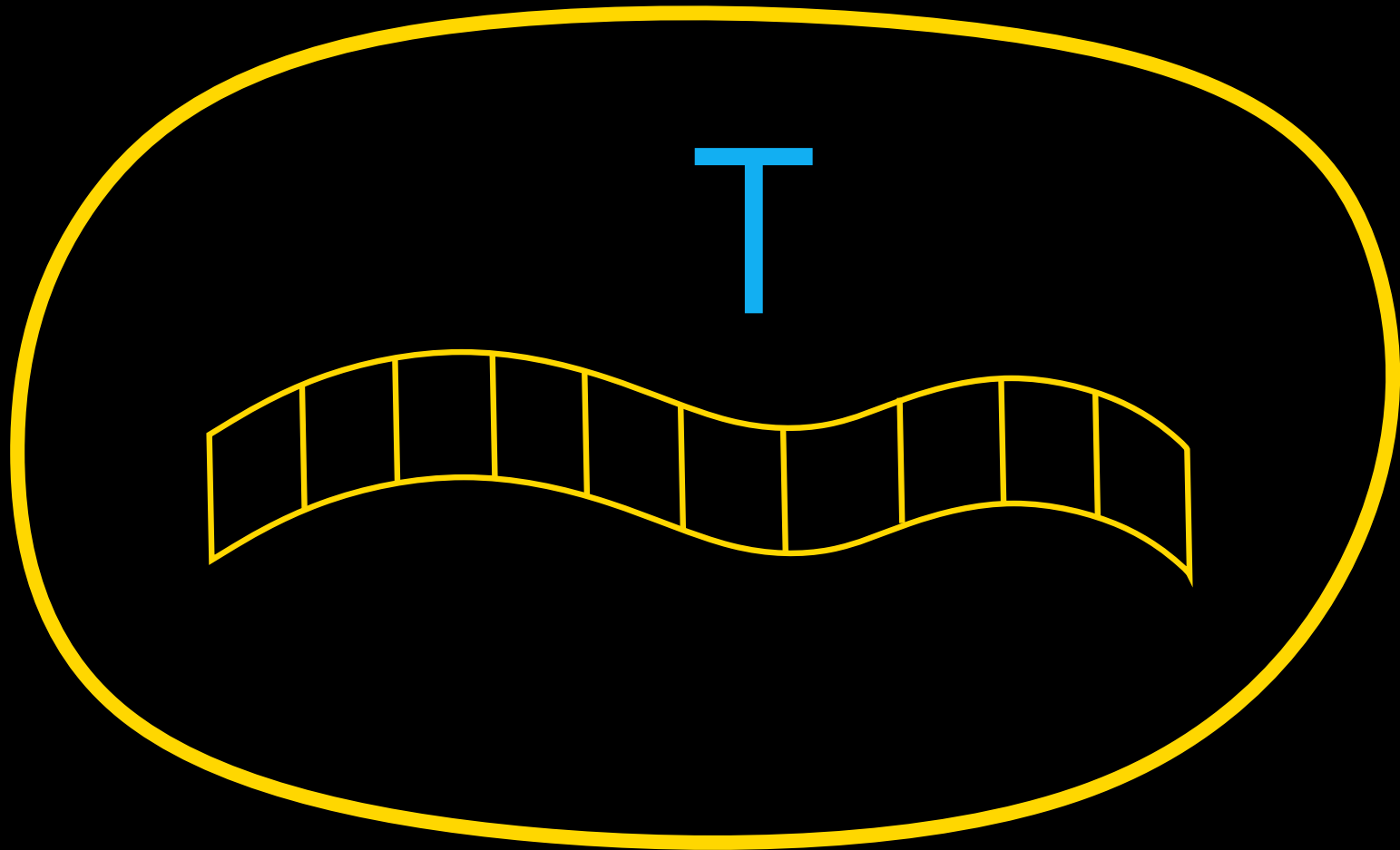
Algorithm 1

IMPLEMENTATION



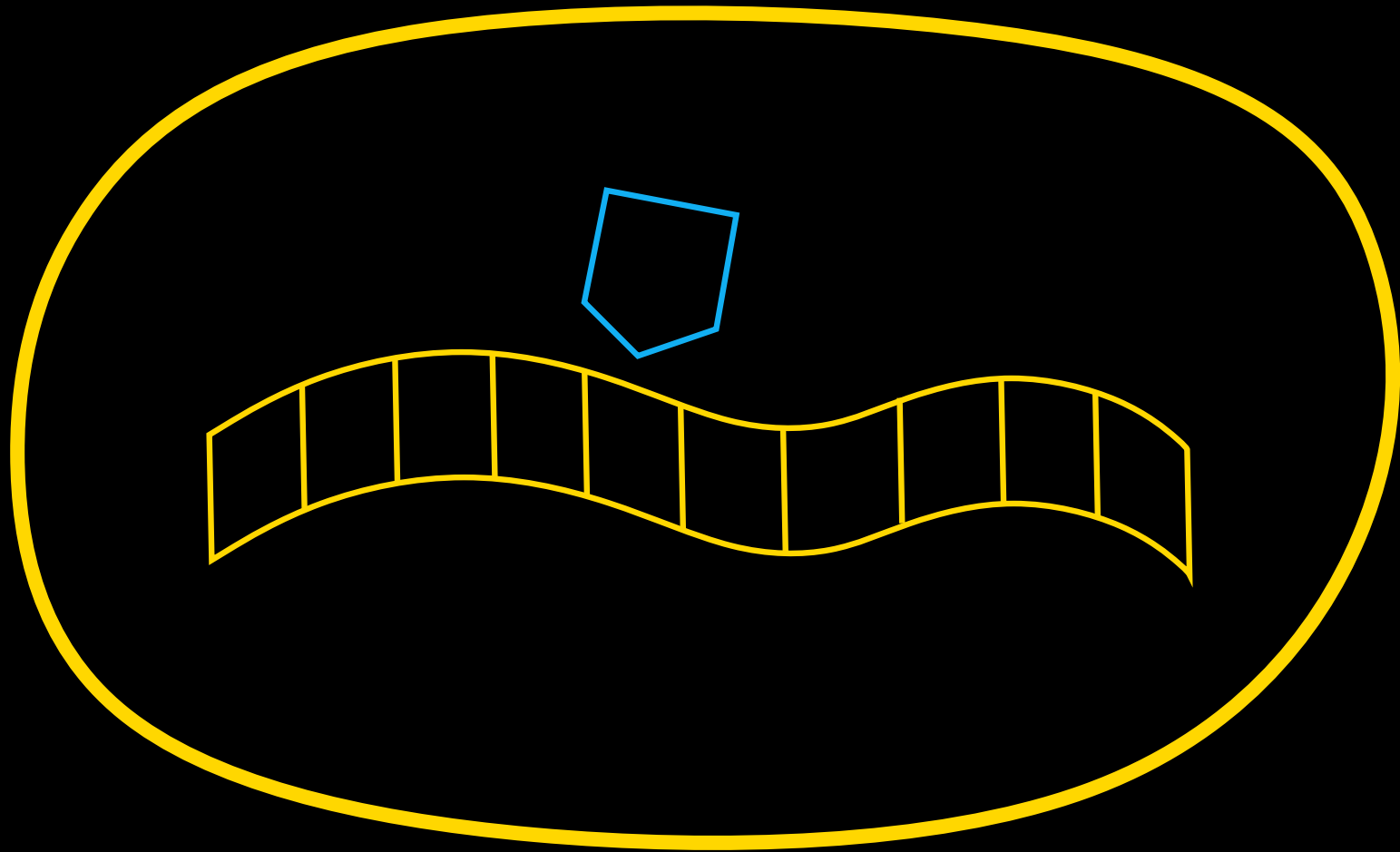
Algorithm 1

IMPLEMENTATION



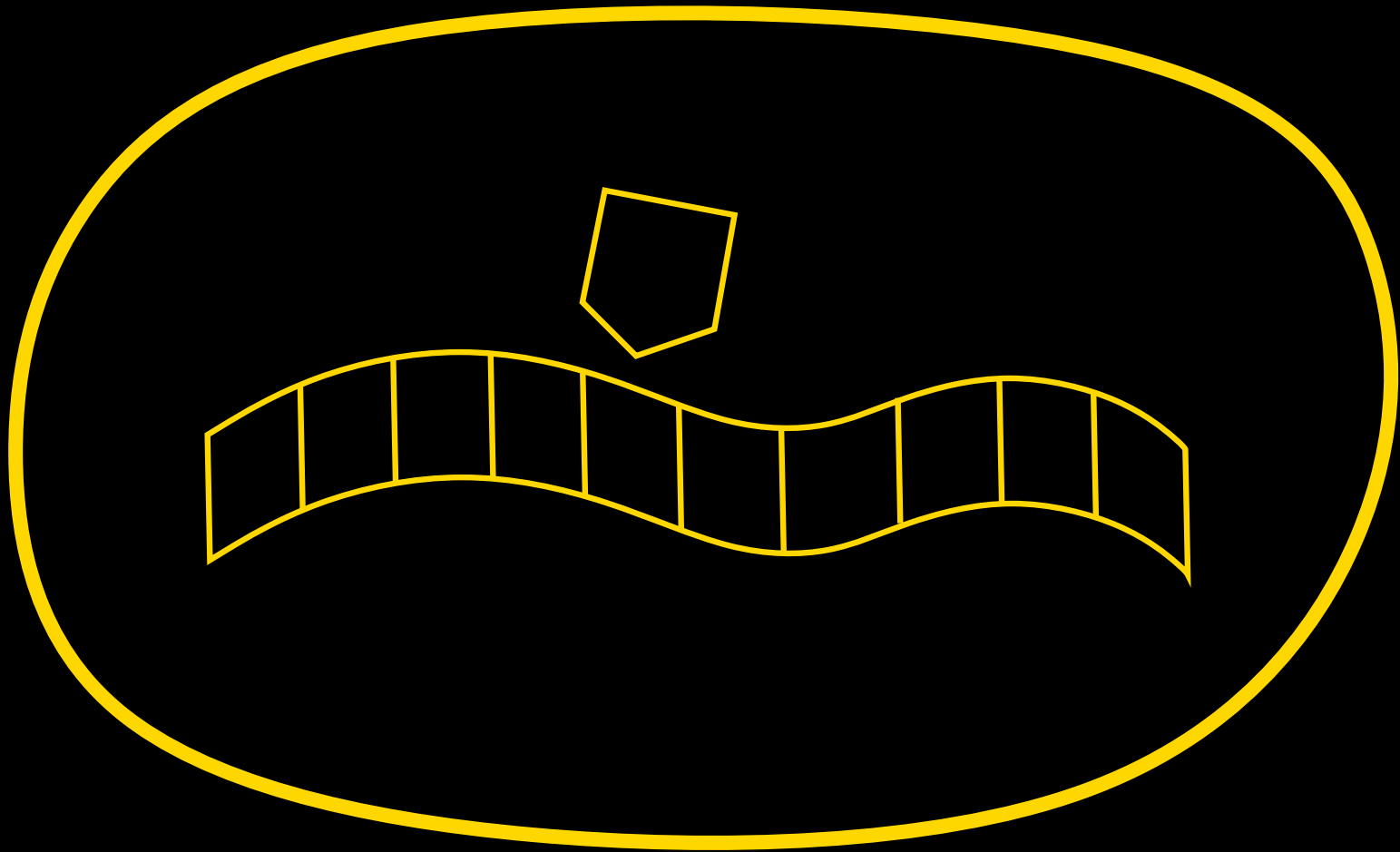
Algorithm 1

IMPLEMENTATION



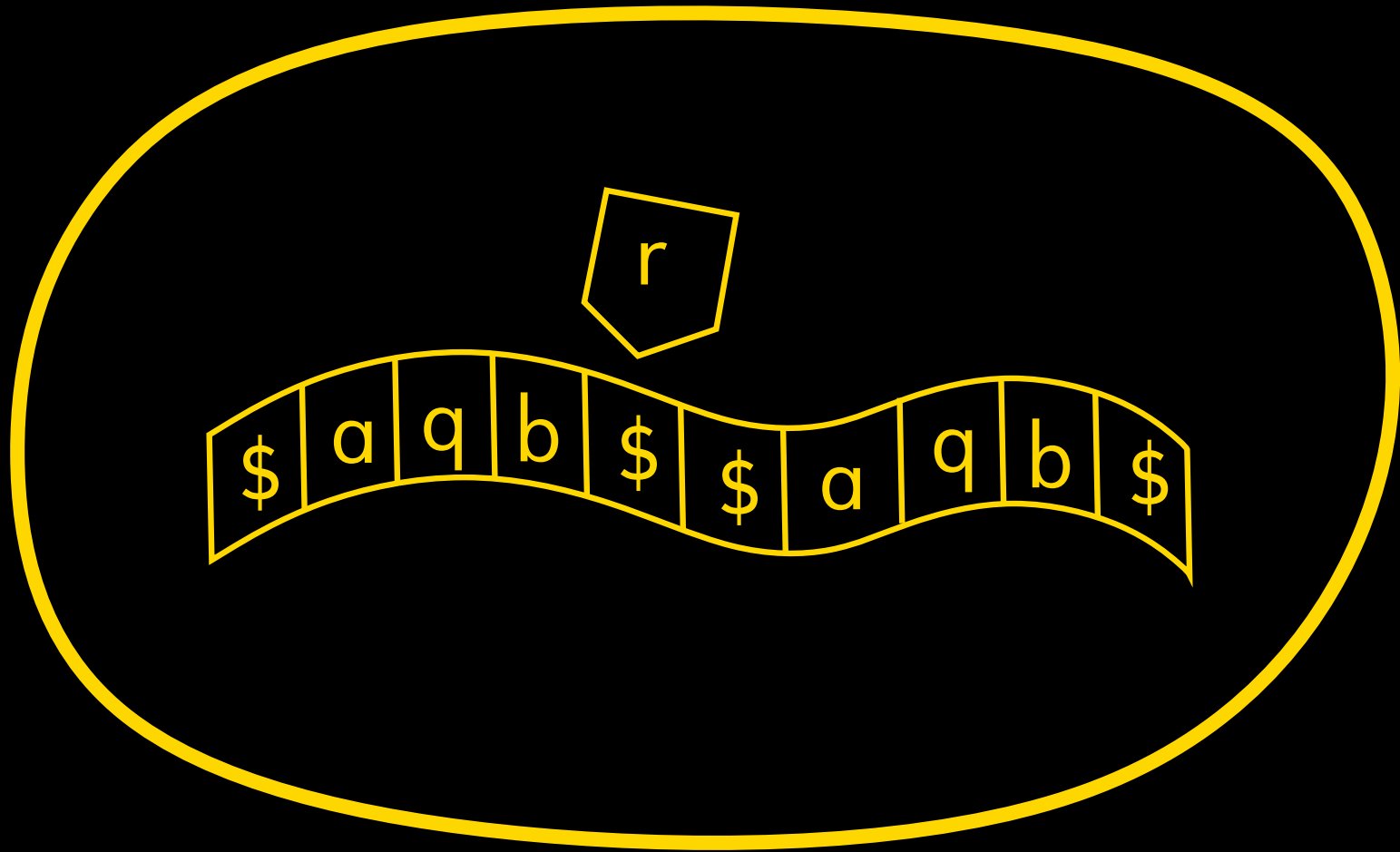
Algorithm II

SIMULATING A TM



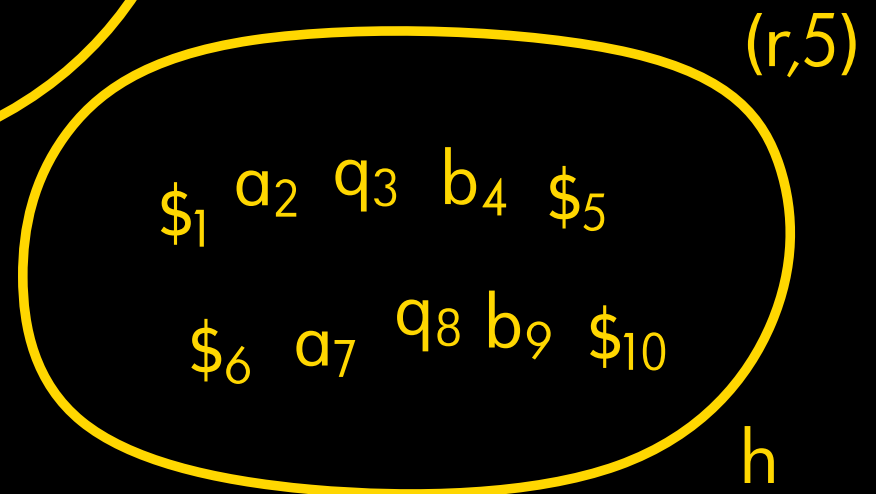
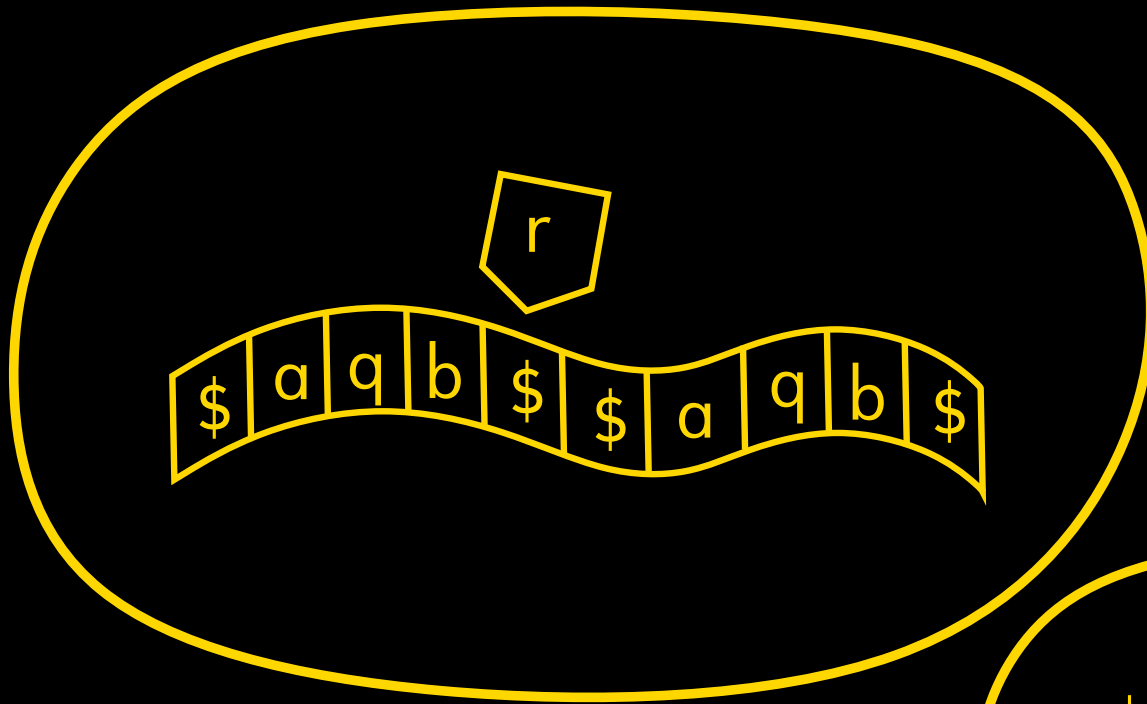
Algorithm II

SIMULATING A TM



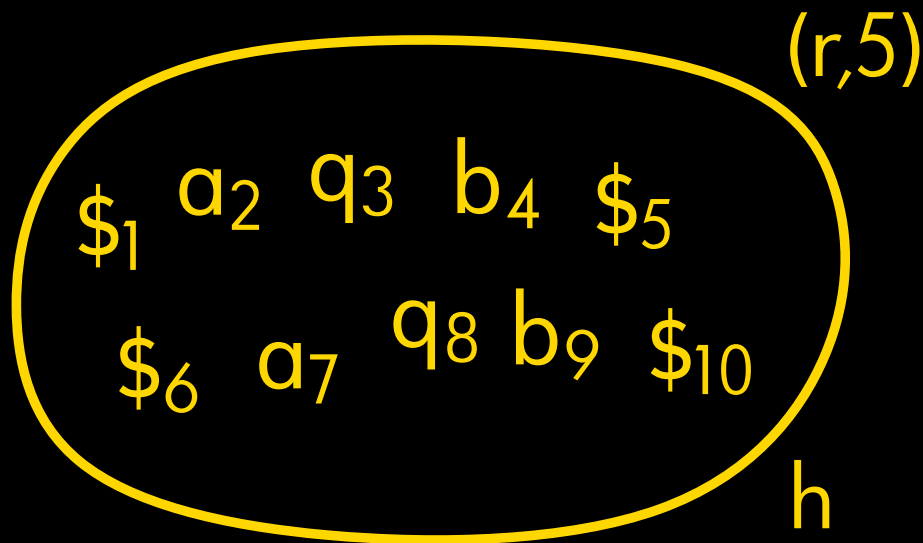
Algorithm II

SIMULATING A TM



Algorithm II

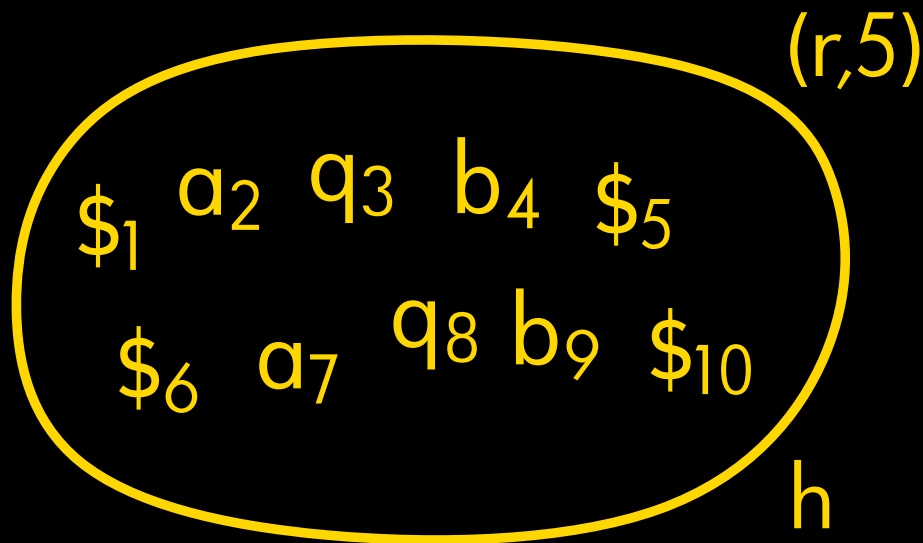
SIMULATING A TM



$$\delta(r, \$) = (s, c, +1)$$

Algorithm II

SIMULATING A TM

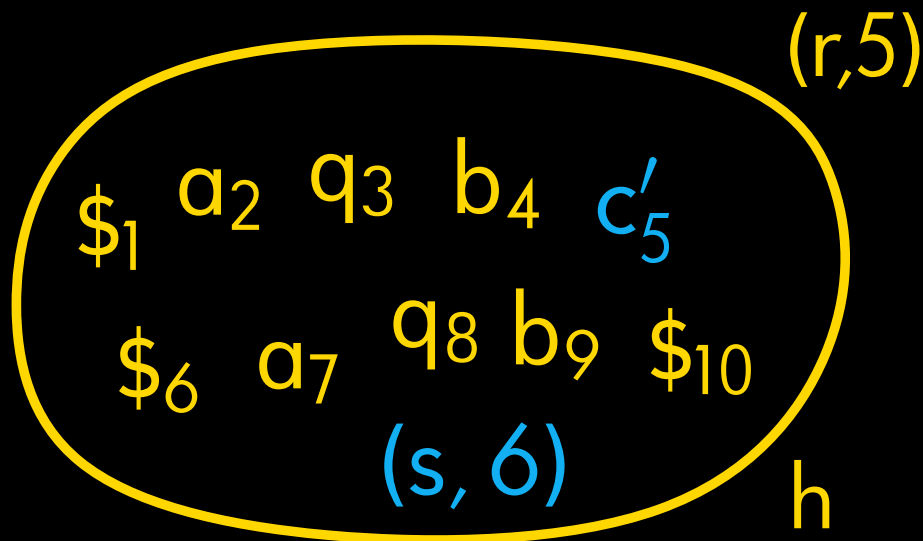


$$[\$5 \rightarrow c'_5 (s, 6)]_h^{(r,5)}$$

$$\delta(r, \$) = (s, c, +1)$$

Algorithm II

SIMULATING A TM

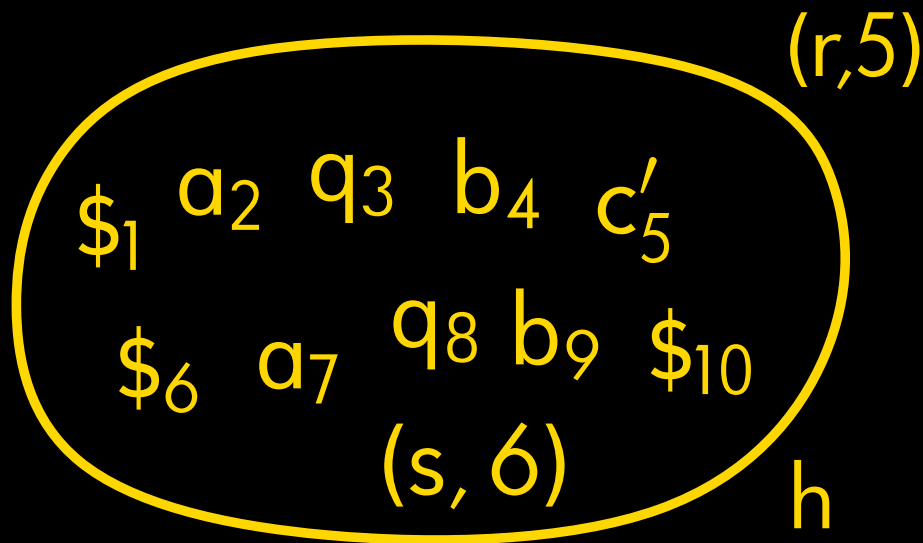


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Algorithm II

SIMULATING A TM



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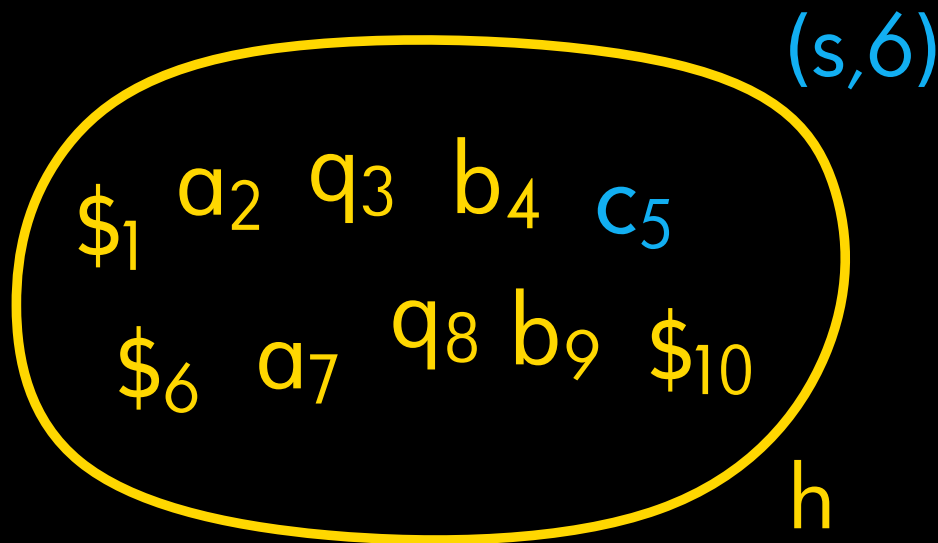
$$[c'_5 \rightarrow c_5]_h^{(r,5)}$$

$$[(s, 6)]_h^{(r,5)} \rightarrow []_h^{(s,6)} \#$$

$$\delta(r, \$) = (s, c, +1)$$

Algorithm II

SIMULATING A TM



$$[\$5 \rightarrow c'_5 (s, 6)]_h^{(r,5)}$$

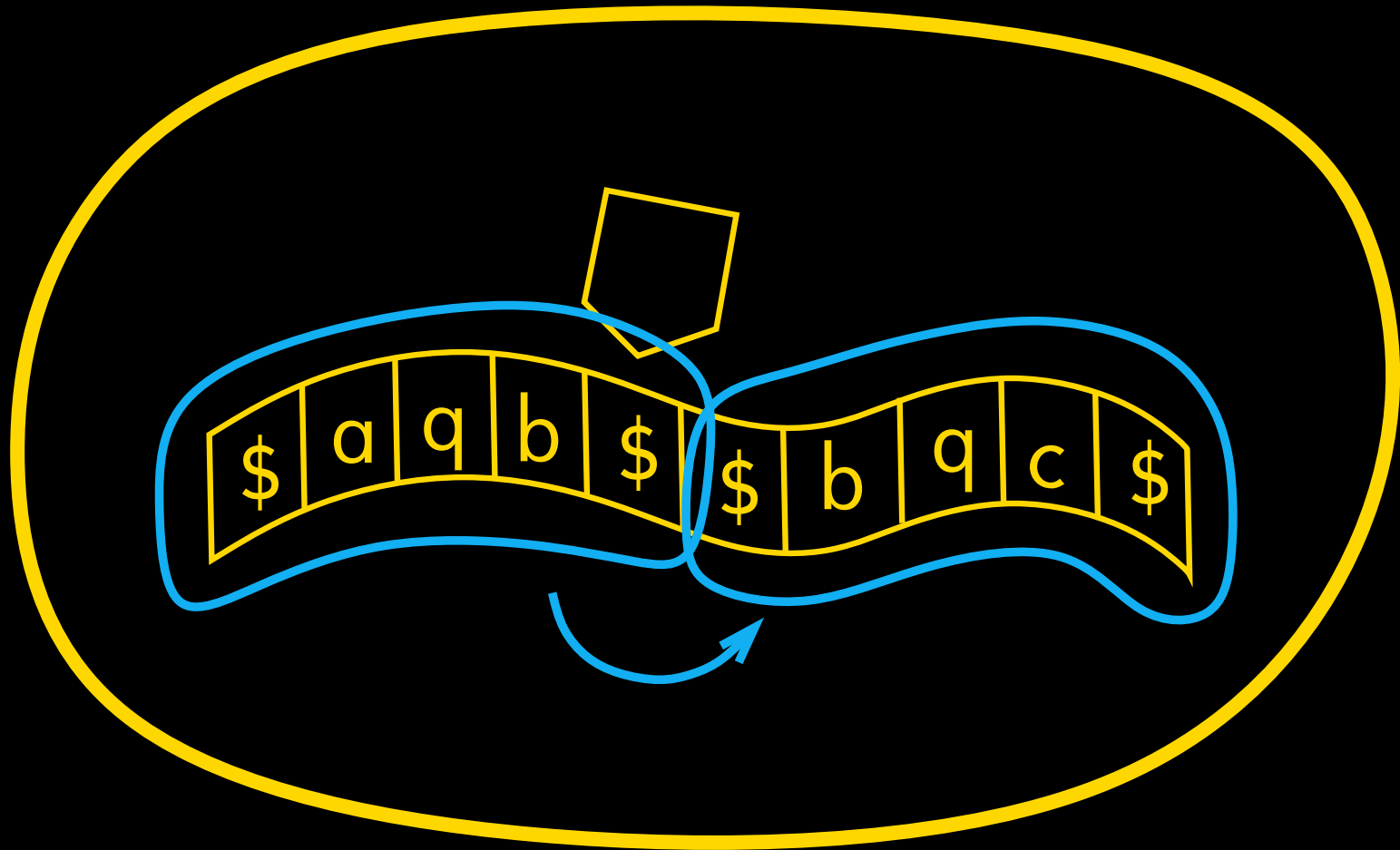
$$[c'_5 \rightarrow c_5]_h^{(r,5)}$$

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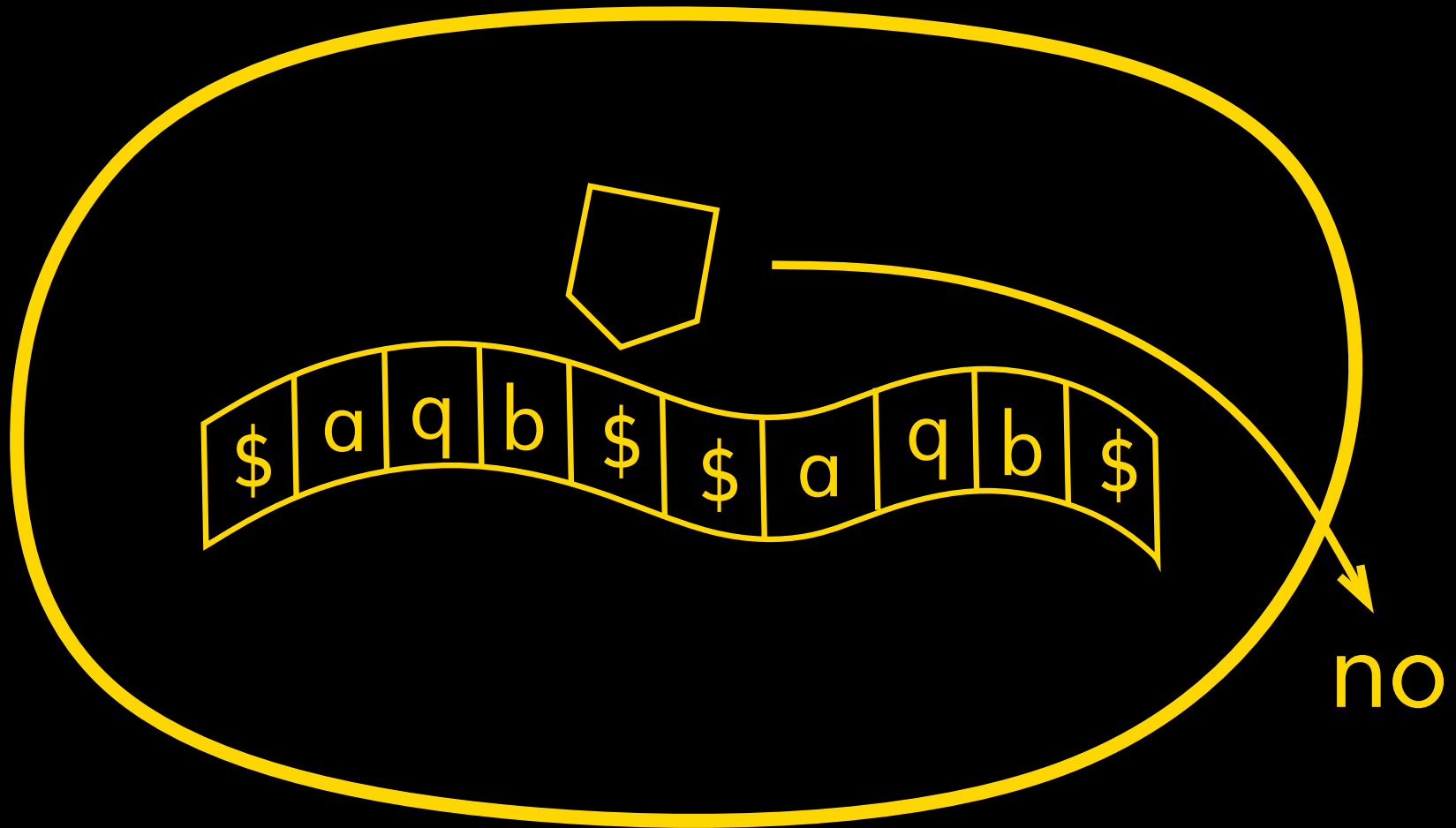
Algorithm II

SIMULATING A TM



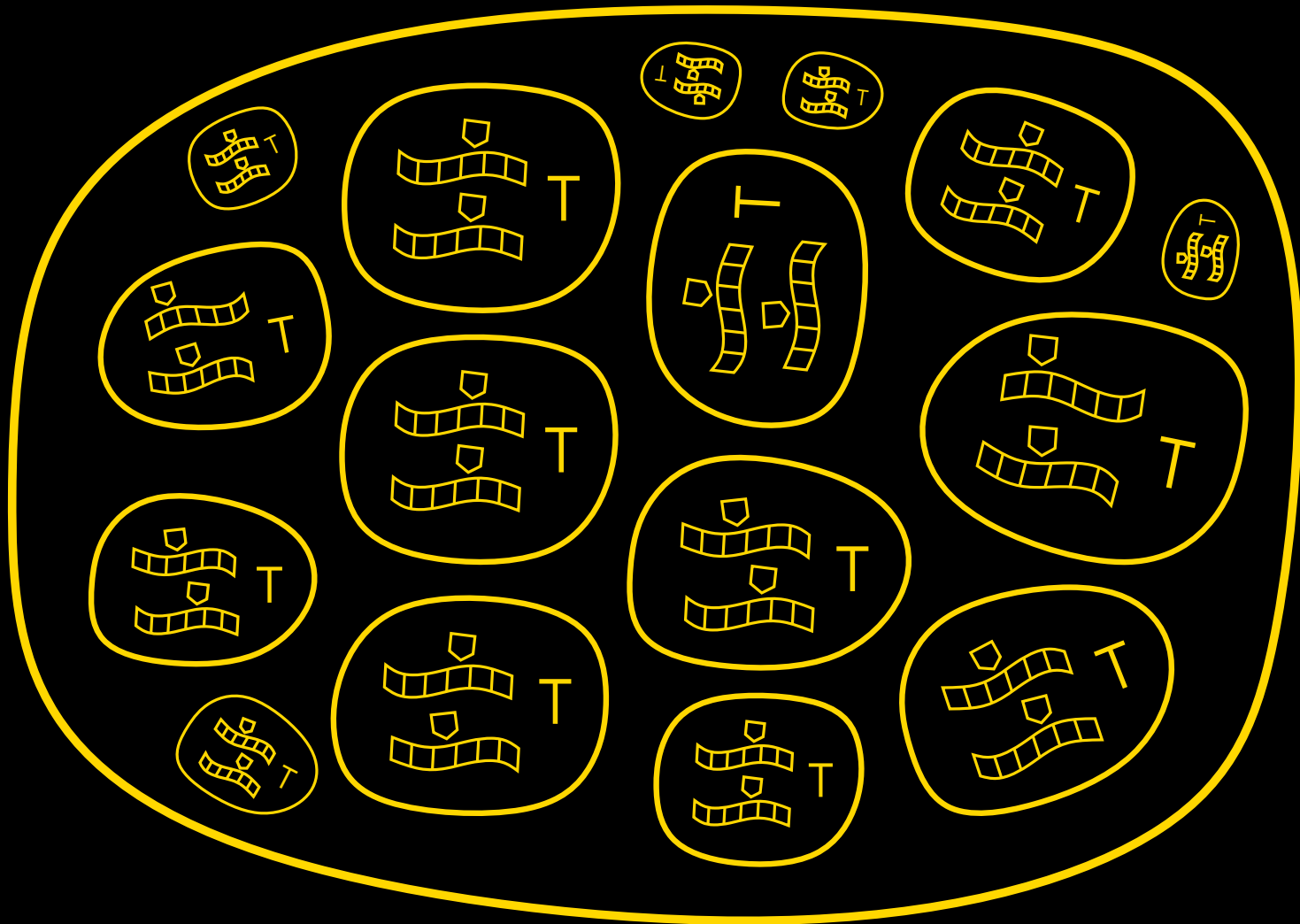
Algorithm II

SIMULATING A TM



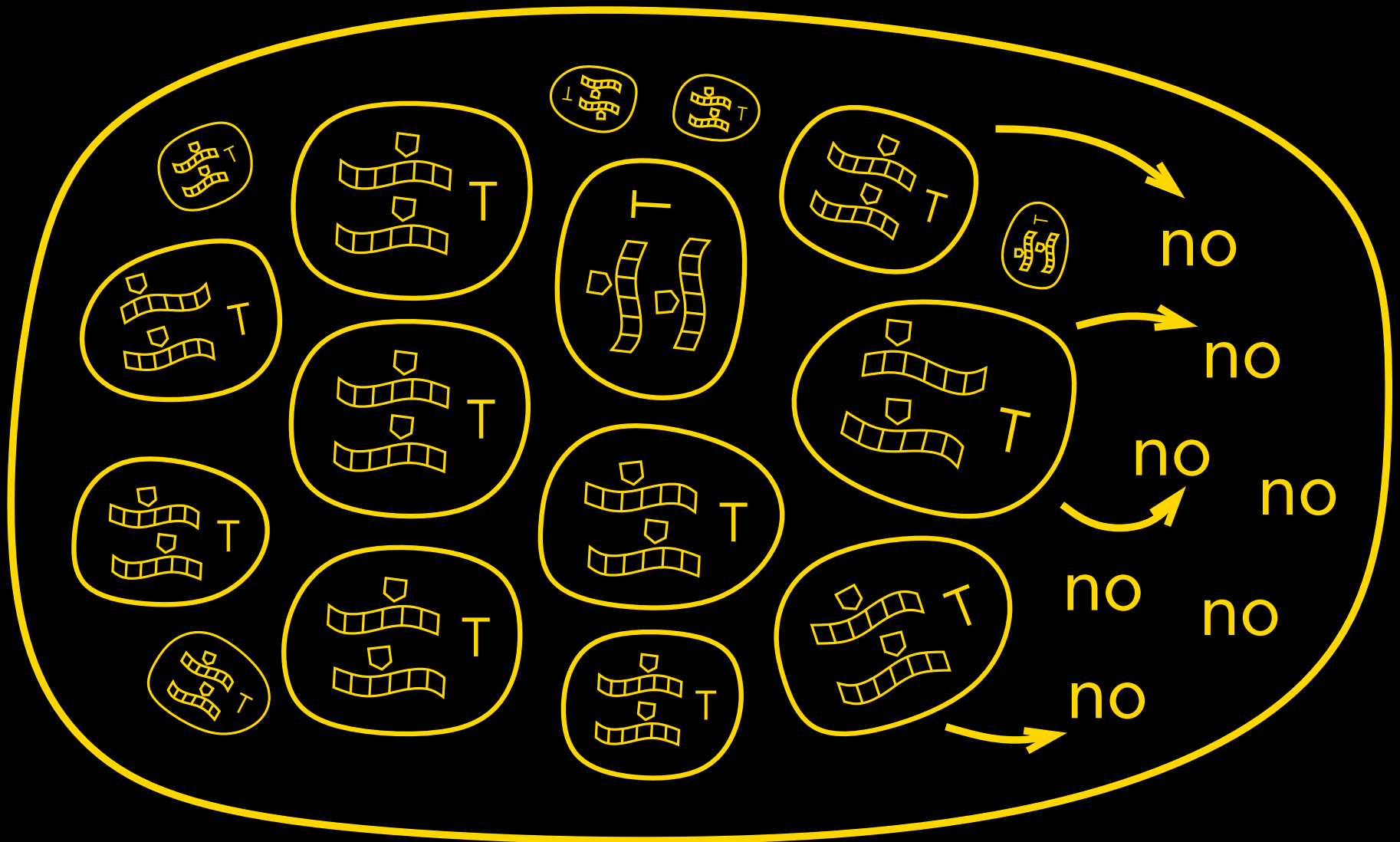
Algorithm I

IMPLEMENTATION



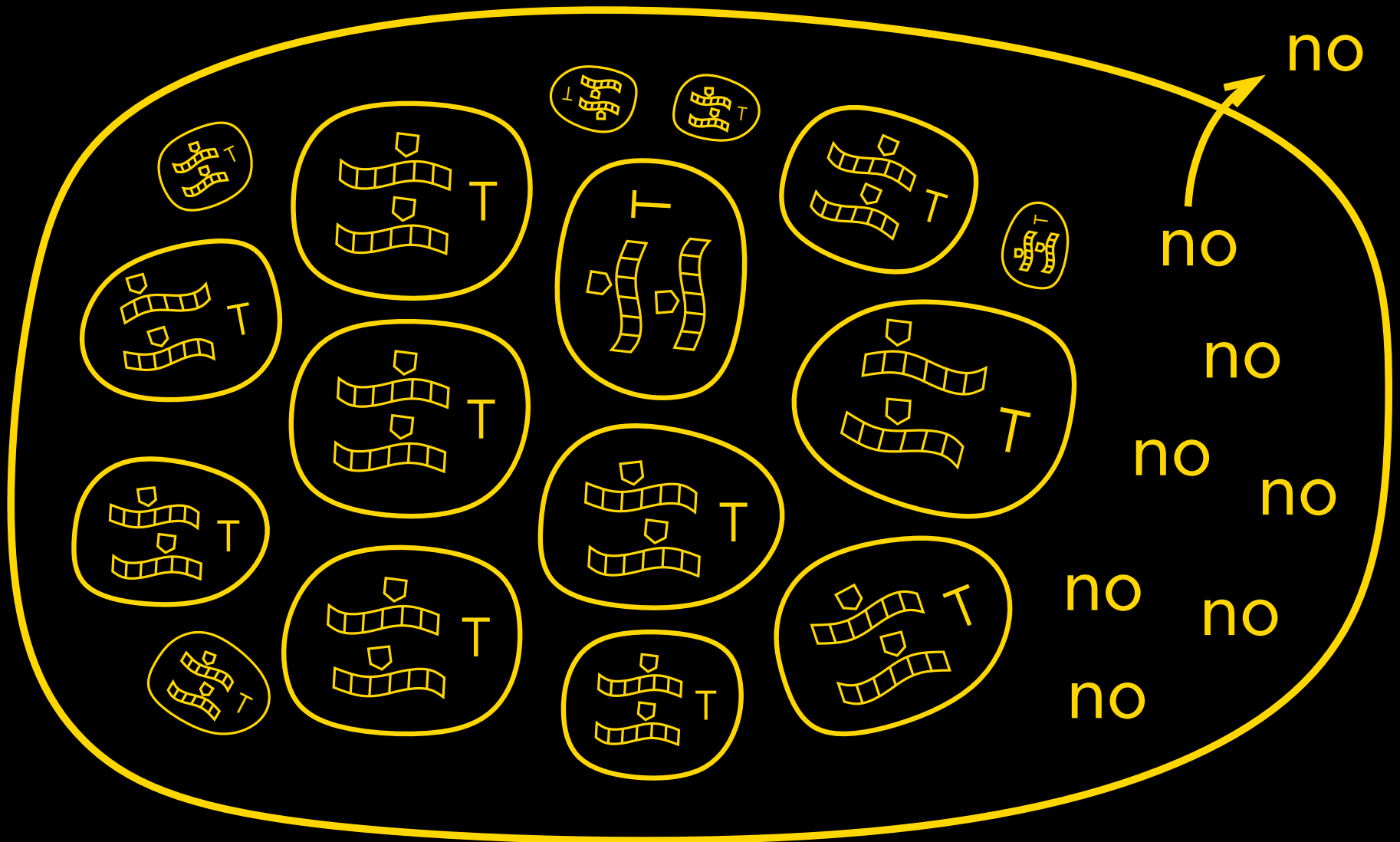
Algorithm I

IMPLEMENTATION



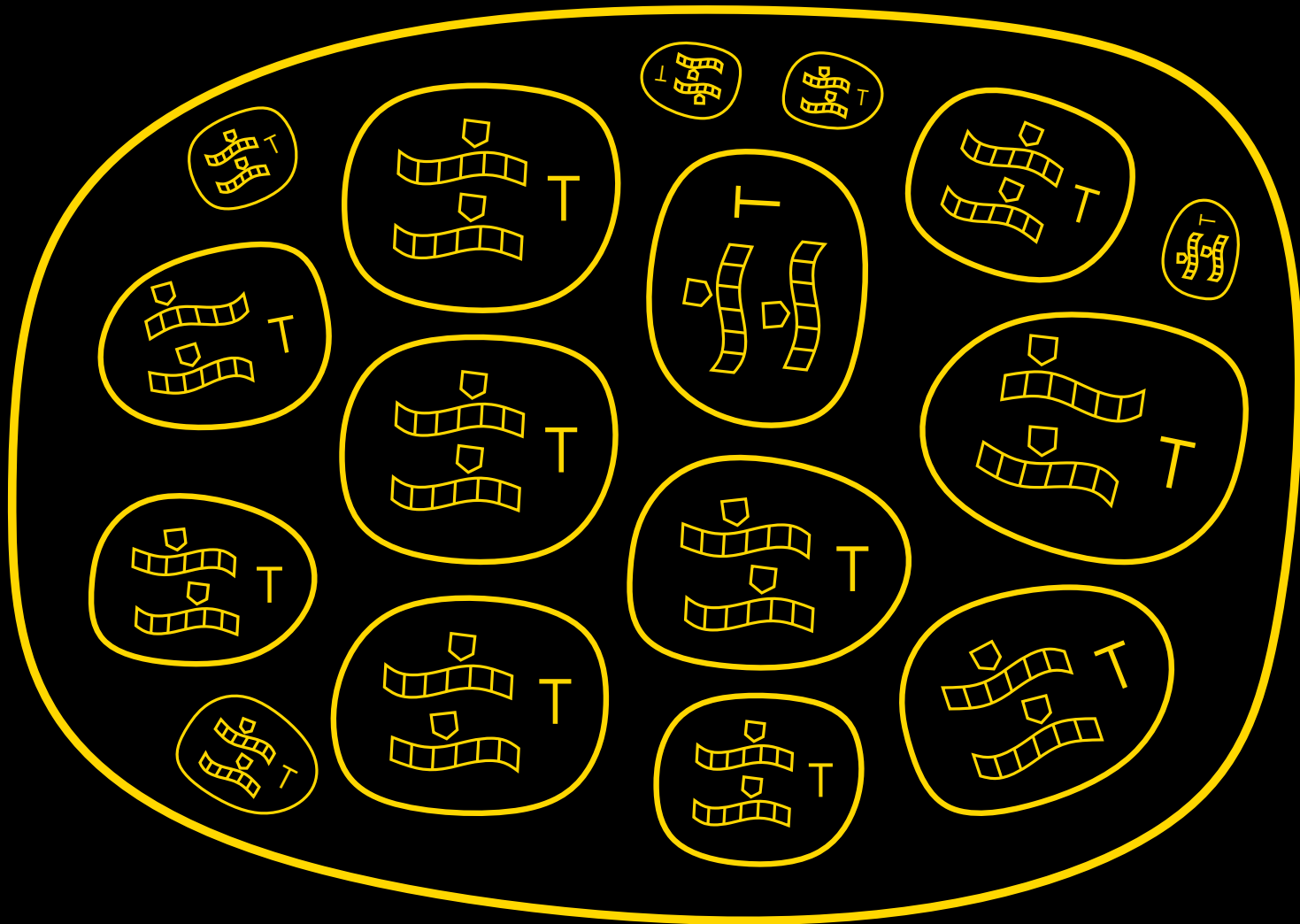
Algorithm I

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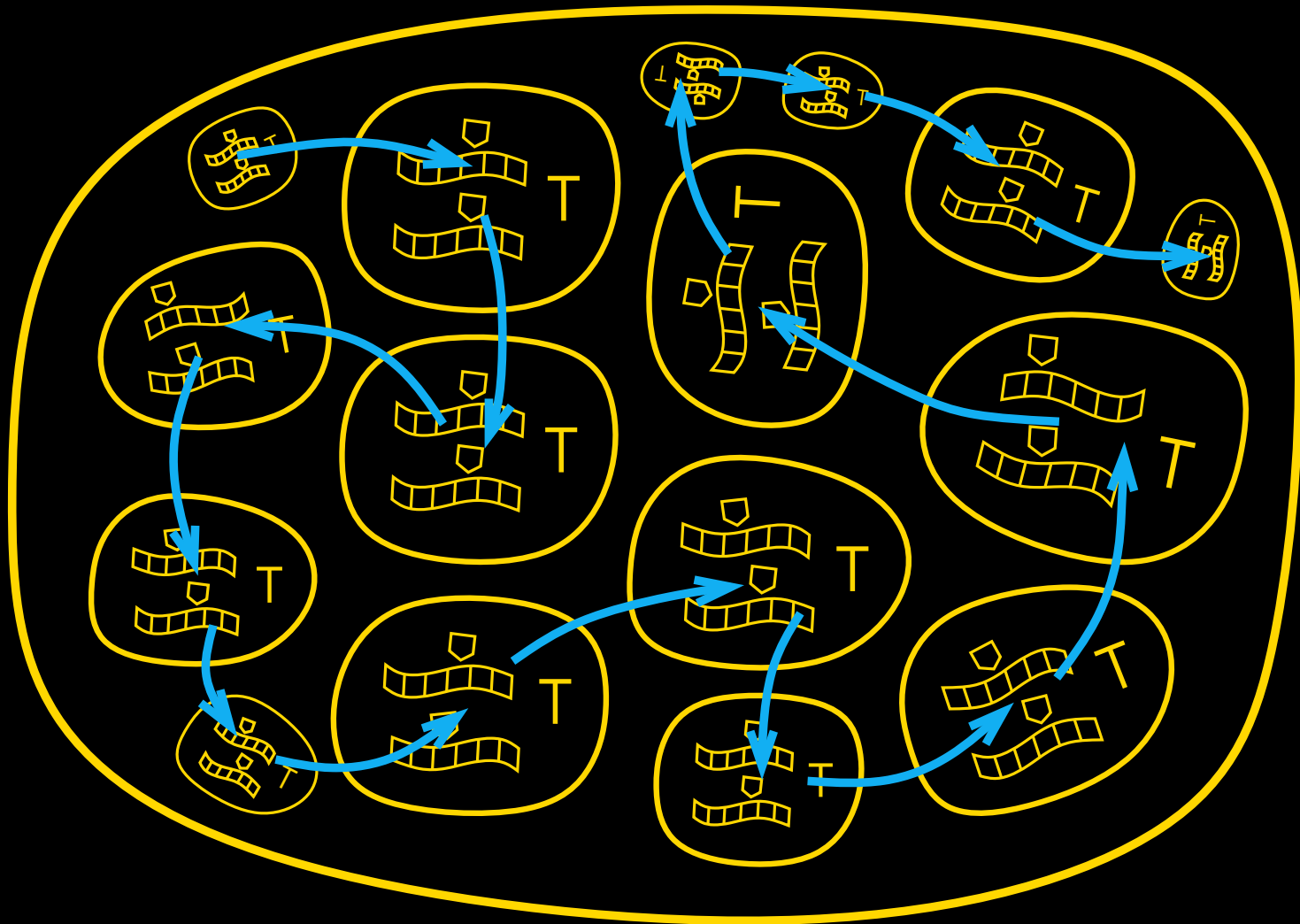
Algorithm I

IMPLEMENTATION



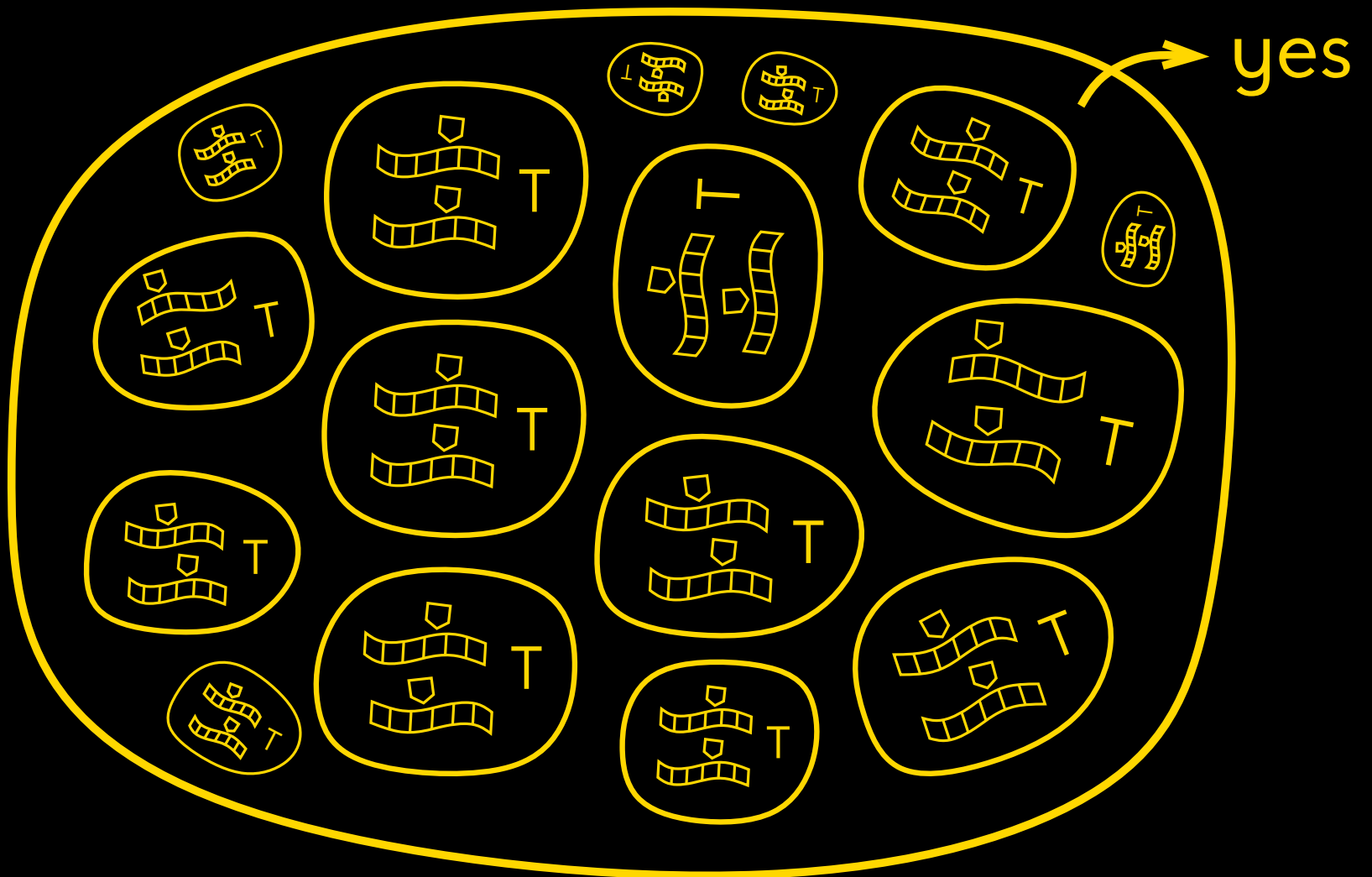
Algorithm I

IMPLEMENTATION



Algorithm I

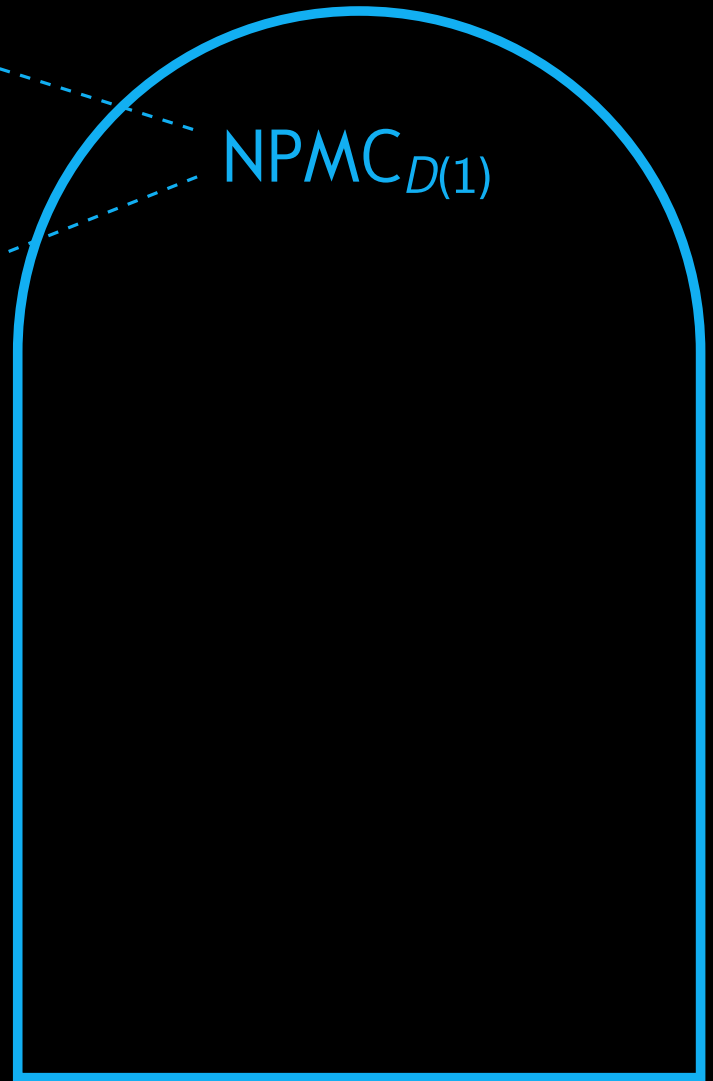
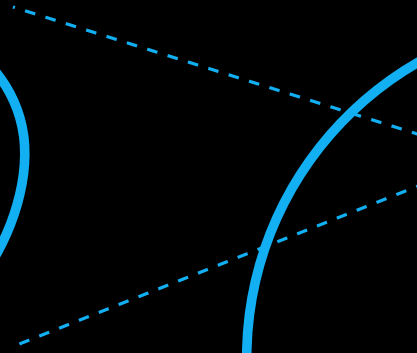
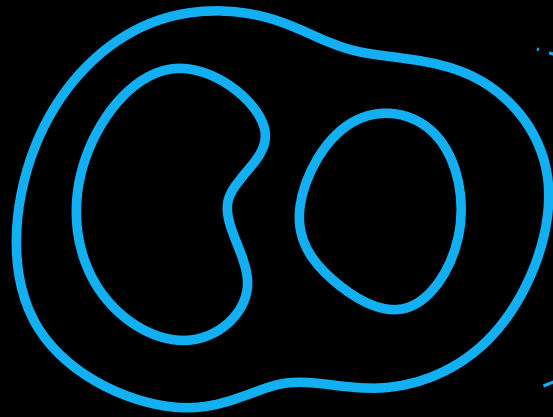
IMPLEMENTATION

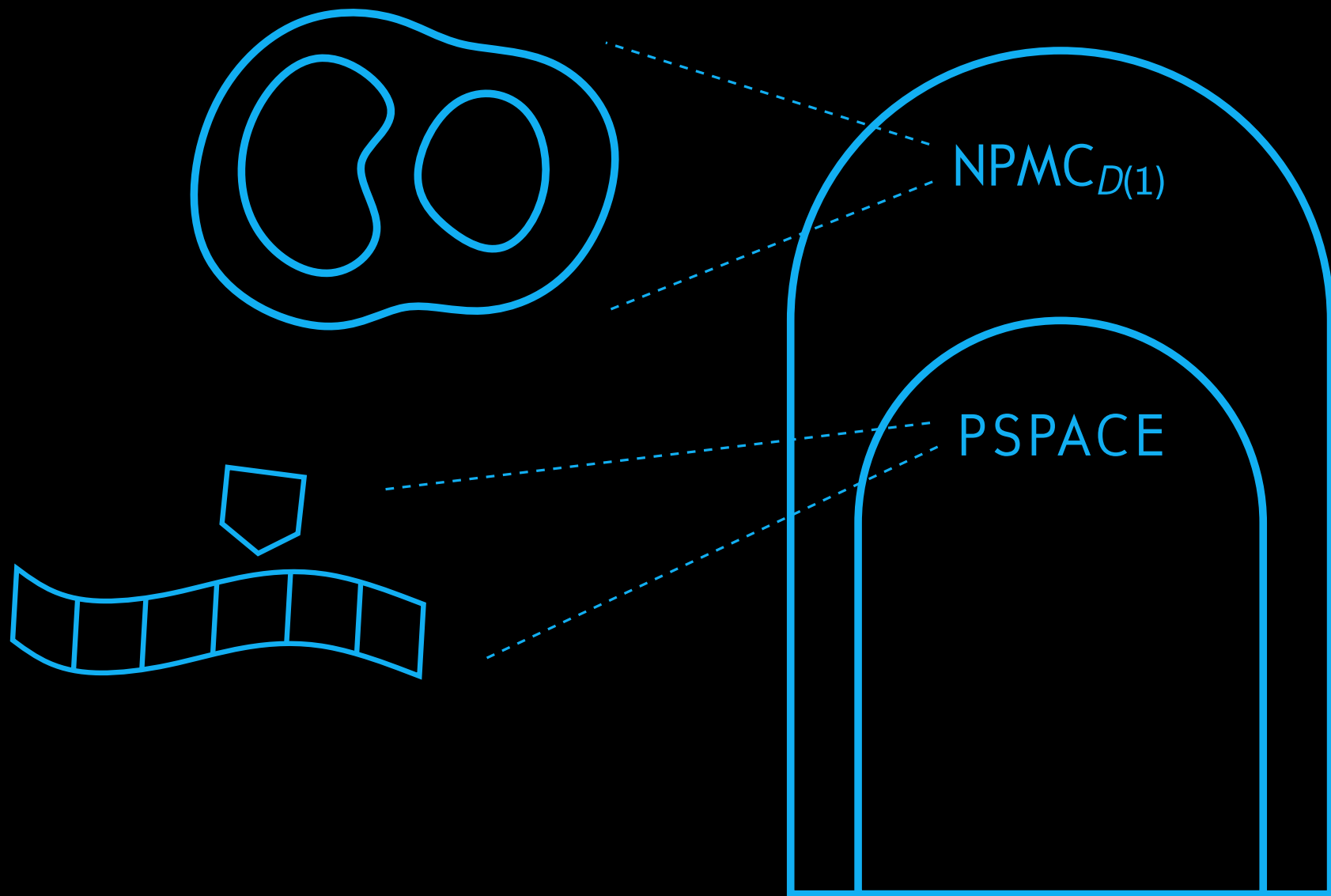


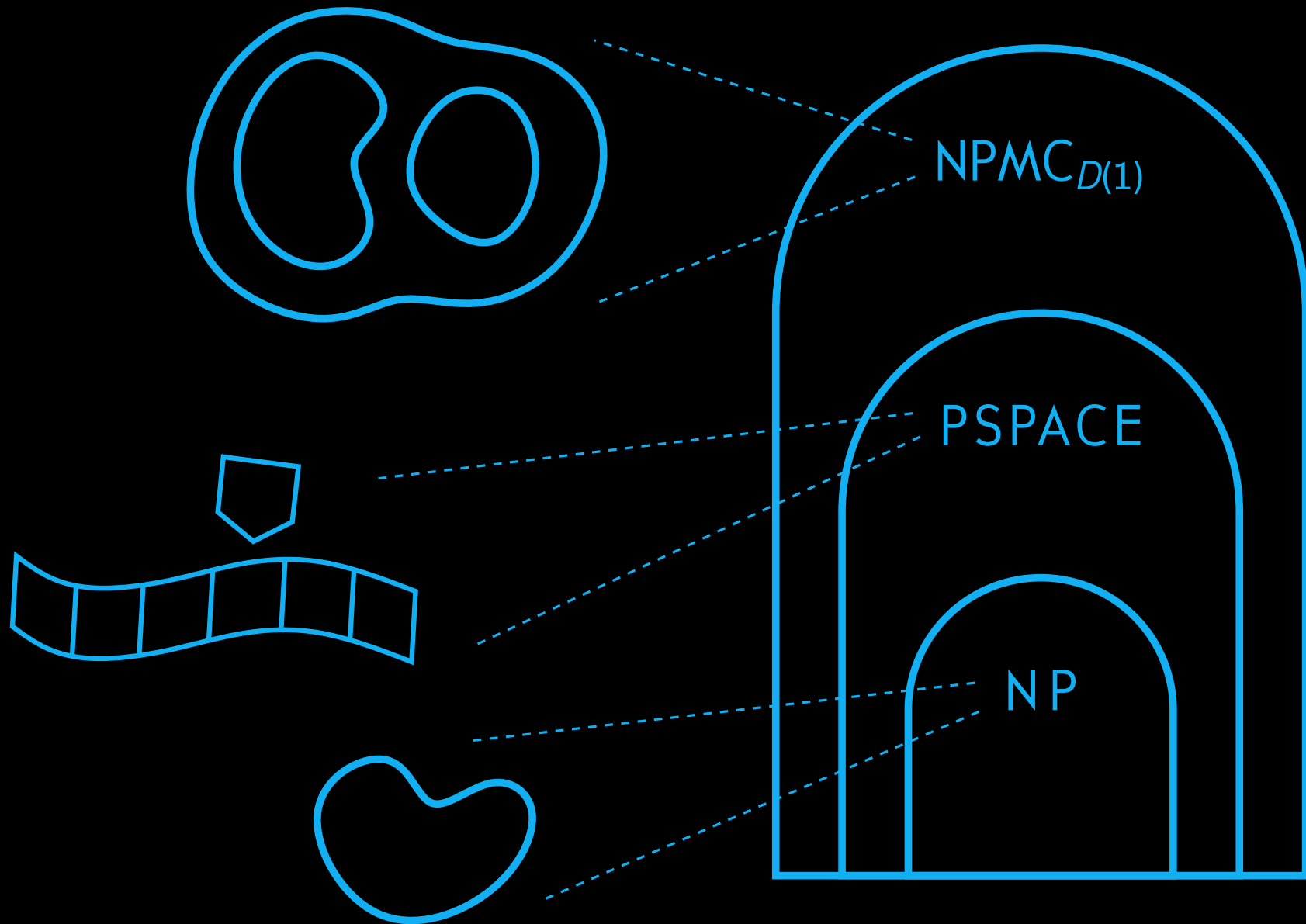
Theorem 1

A NEW RESULT

SHALLOW NON-CONFLUENT P systems with active membranes can simulate polynomial-SPACE nondeterministic Turing machines in polynomial TIME, and thus solve all PSPACE problems and restore efficiency to the galaxy....







Theorem 1'

MORE SPECIFICALLY

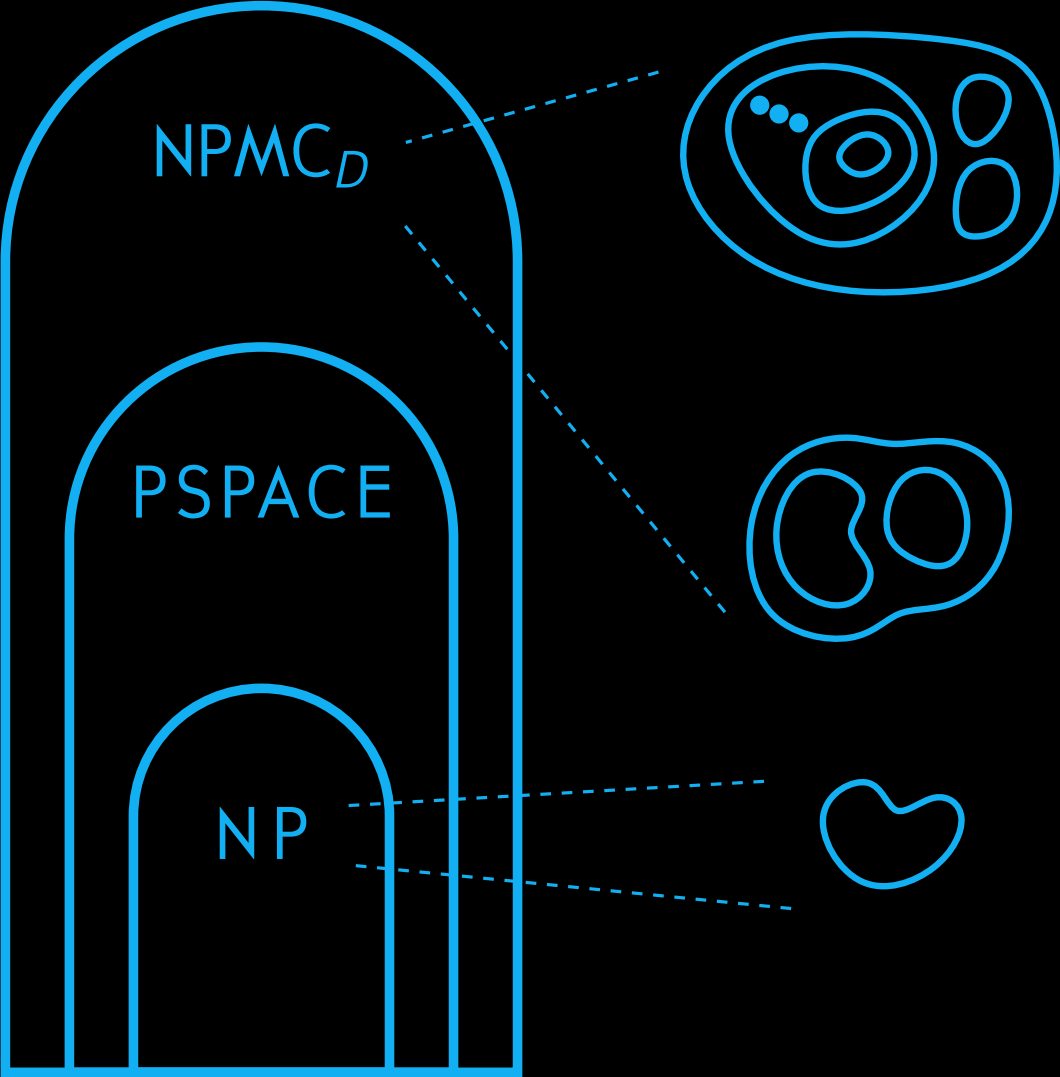
SHALLOW MONODIRECTIONAL NON-CONFLUENT P systems with active membranes can simulate polynomial-SPACE nondeterministic Turing machines in polynomial TIME, and thus solve all PSPACE problems and restore efficiency to the galaxy....

Theorem 1'

MORE SPECIFICALLY

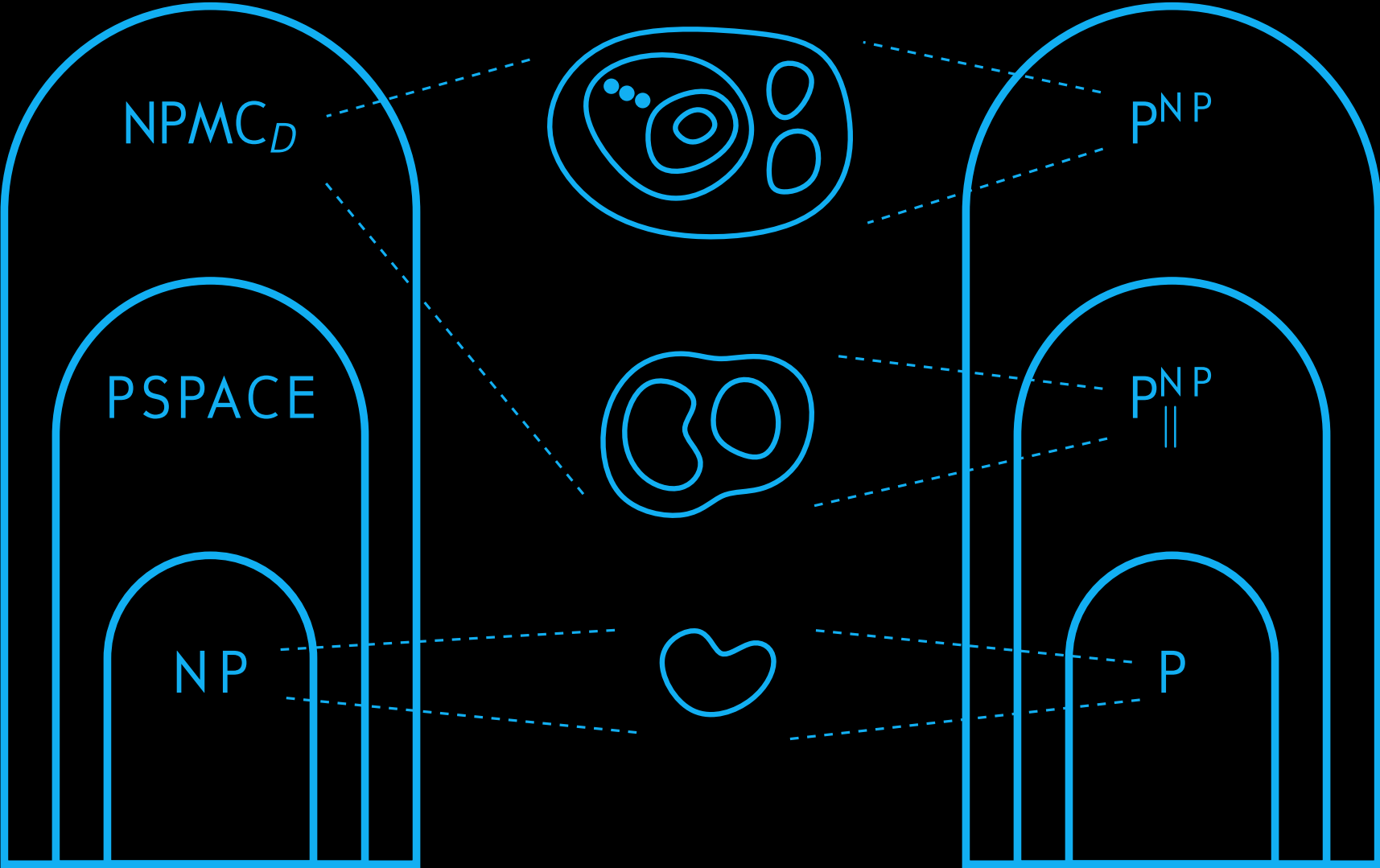
SHALLOW **MONODIRECTIONAL** NON-CONFLUENT P systems with active membranes can simulate polynomial-SPACE nondeterministic Turing machines in polynomial TIME, and thus solve all PSPACE problems and restore efficiency to the galaxy....

NON-CONFLUENT



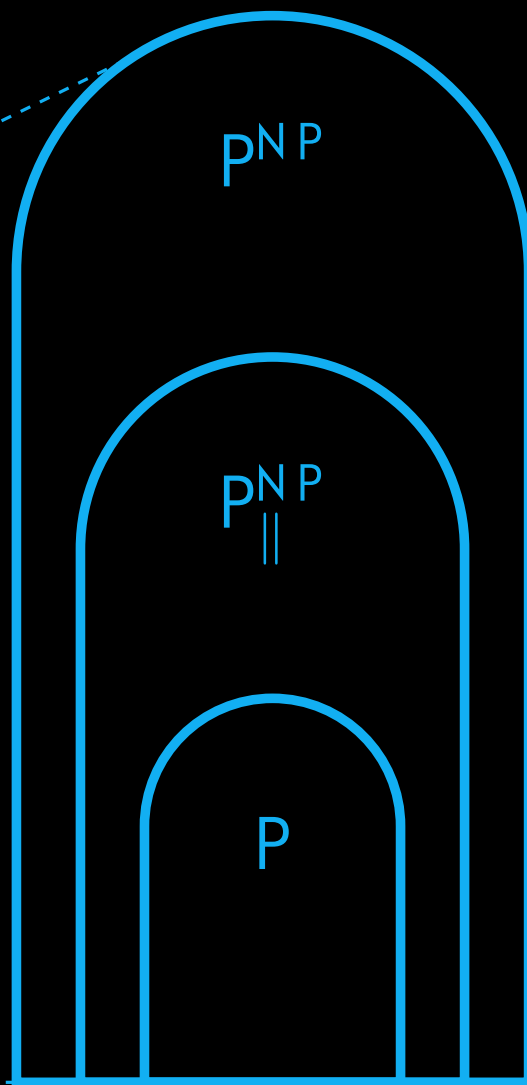
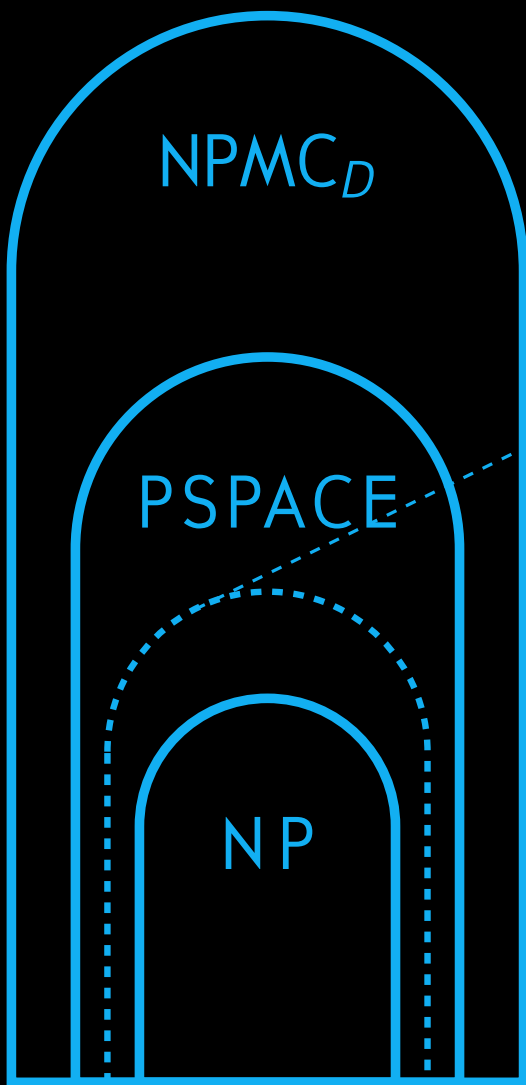
NON-CONFLUENT

CONFLUENT



NON-CONFLUENT

CONFLUENT



Open Problem I

UPPER BOUNDS

UPPER BOUNDS for polynomial-time non-confluent P systems of depth 1 and unbounded depth are still unknown....

Open Problem II

INTERMEDIATE CLASSES

Find a combination of features (e.g., available rules) in order to characterise non-confluent **COMPLEXITY CLASSES** between NP and PSPACE....

Open Problem III

OTHER MODELS

TISSUE P SYSTEMS with division look similar to P systems with active membranes of depth 1. Maybe they have the same power when non-confluent too....

Thanks for your Attention!
Grazie per la vostra Attenzione!

ANY QUESTIONS?



CMC17