Recuperació de la informació

- Modern Information Retrieval (1999)
  Ricardo-Baeza Yates and Berthier Ribeiro-Neto

- Flexible Pattern Matching in Strings (2002)
  Gonzalo Navarro and Mathieu Raffinot

- http://www-igm.univ-mlv.fr/~lecroq/string/index.html

Algorismes de:

Cerca de patrons (exacta i aproximada)
(String matching i Pattern matching)

Indexació de textos:
Suffix trees, Suffix arrays

String Matching

String matching: definition of the problem (text,pattern)

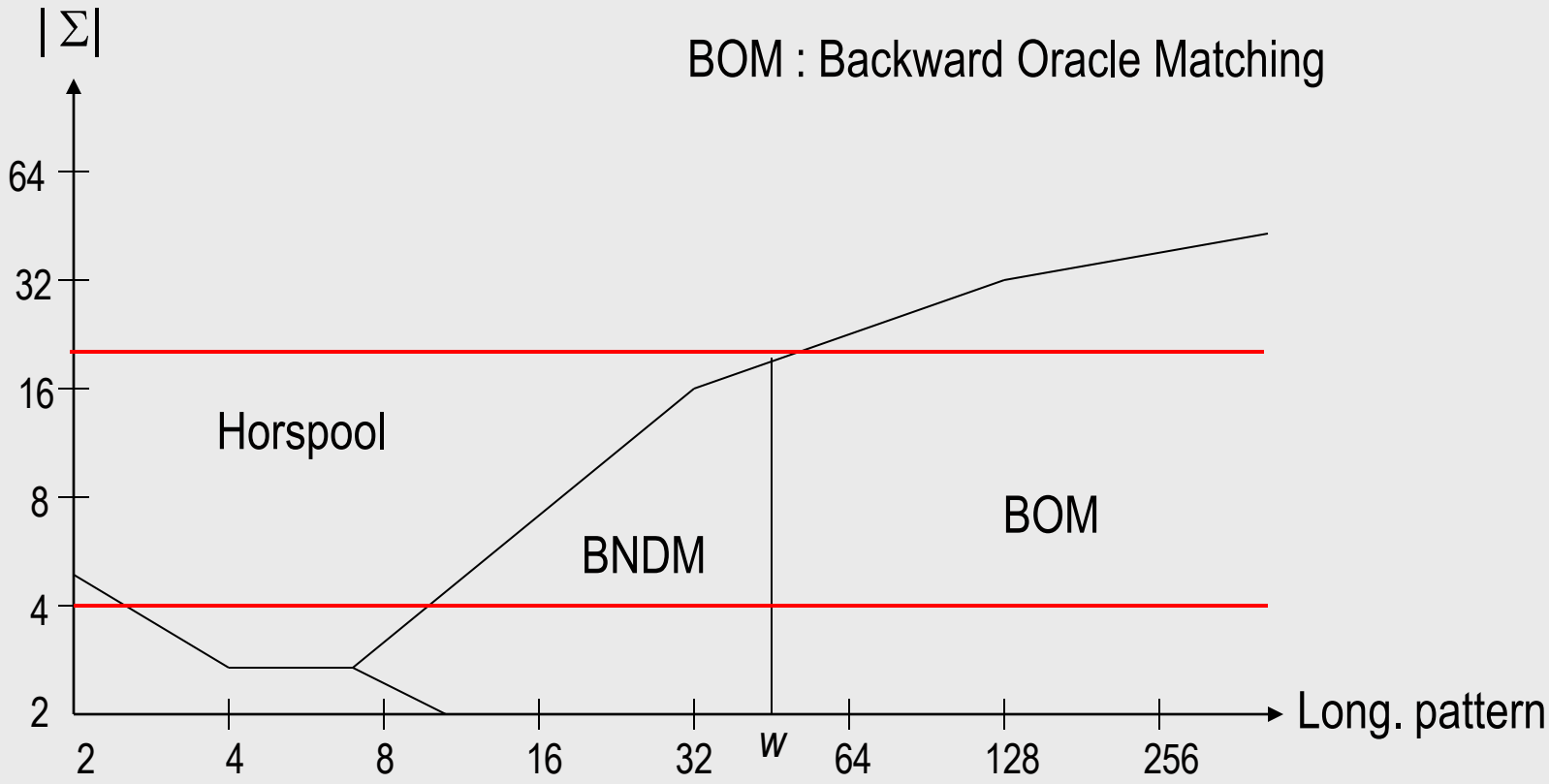
- **Exact matching:** depends on what we have: text or patterns
  - **The patterns ---> Data structures for the patterns**
    - 1 pattern ---> The algorithm depends on |p| and |Σ|
    - k patterns ---> The algorithm depends on k, |p| and |Σ|
  - **Extensions**
  - **Regular Expressions**
  - **The text ----> Data structure for the text (suffix tree, ...)**
- **Approximate matching:**
  - **Dynamic programming**
  - **Sequence alignment (pairwise and multiple)**
  - **Sequence assembly: hash algorithm**
- **Probabilistic search: Hidden Markov Models**

Exact string matching: one pattern (text on-line)

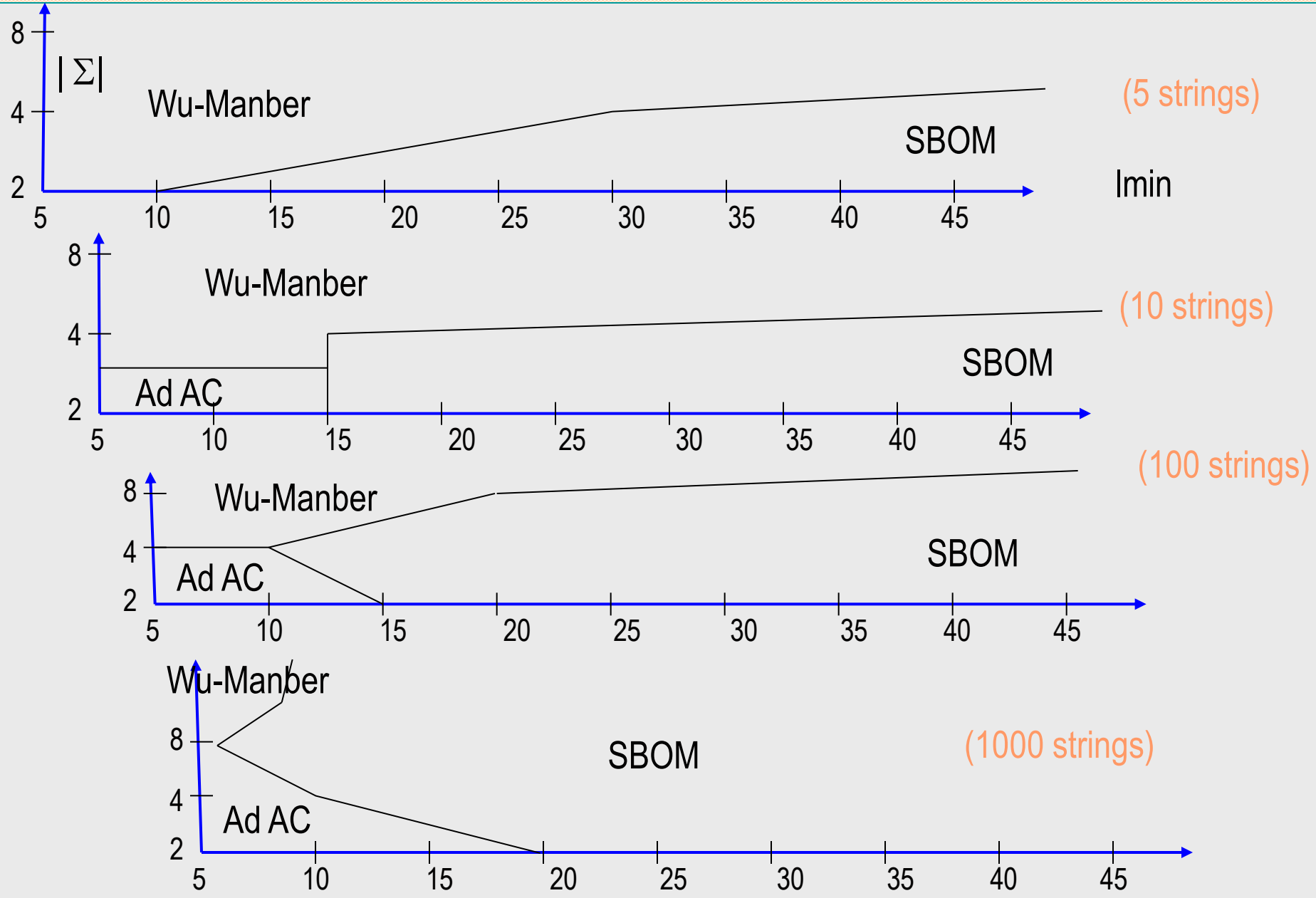
Experimental efficiency (Navarro & Raffinot)

BNDM : Backward Nondeterministic Dawg Matching

BOM : Backward Oracle Matching



Multiple string matching



Trie

Construct the trie of GTATGTA,GTAT,TAATA,GTGTA

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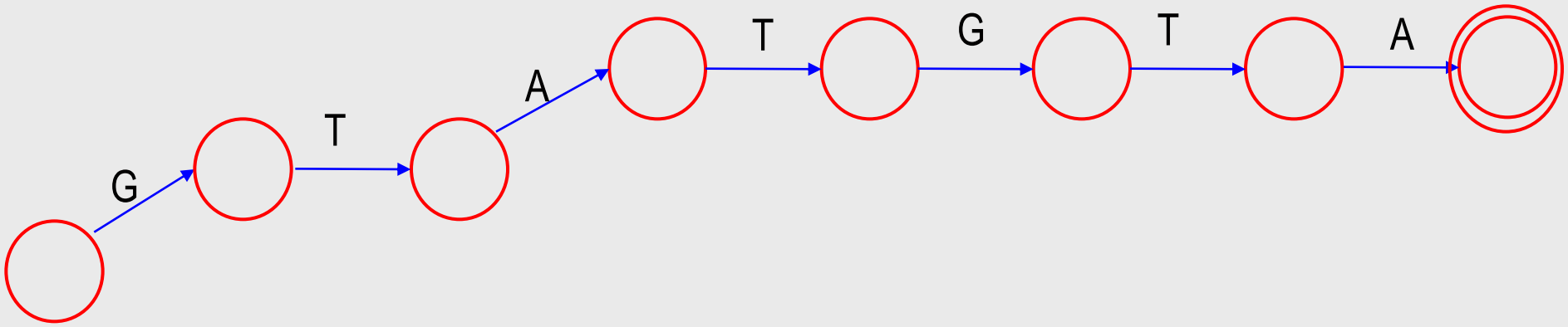

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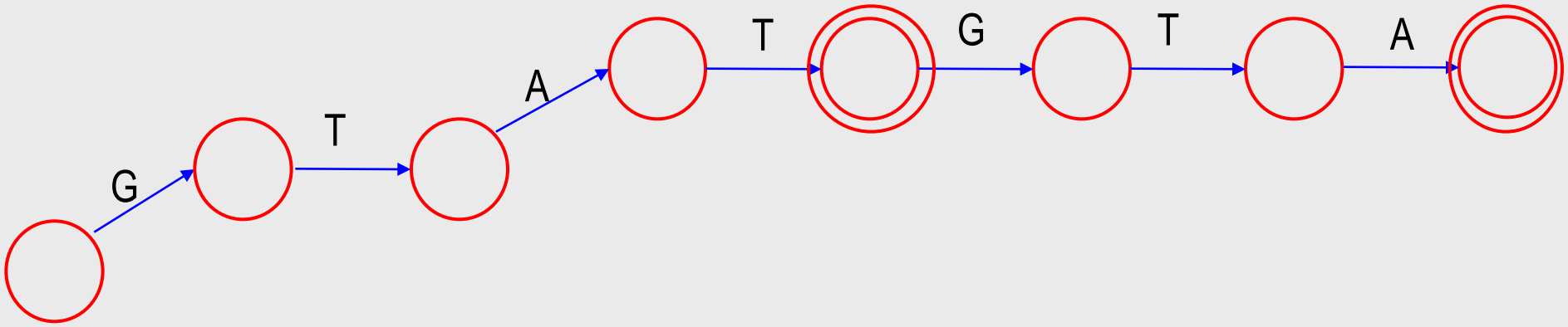

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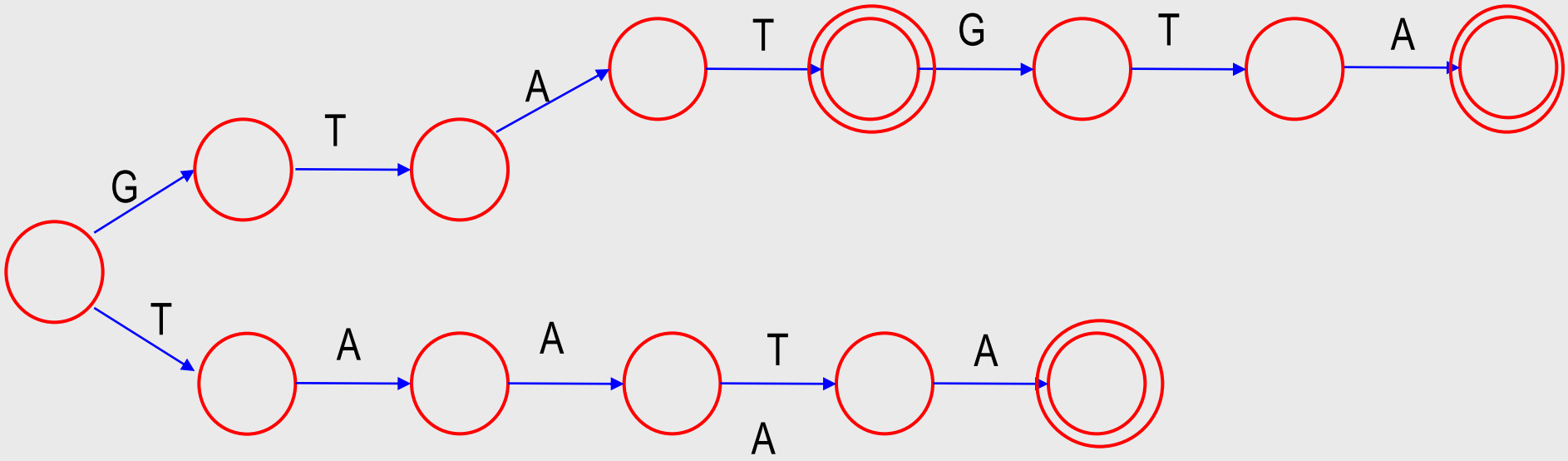

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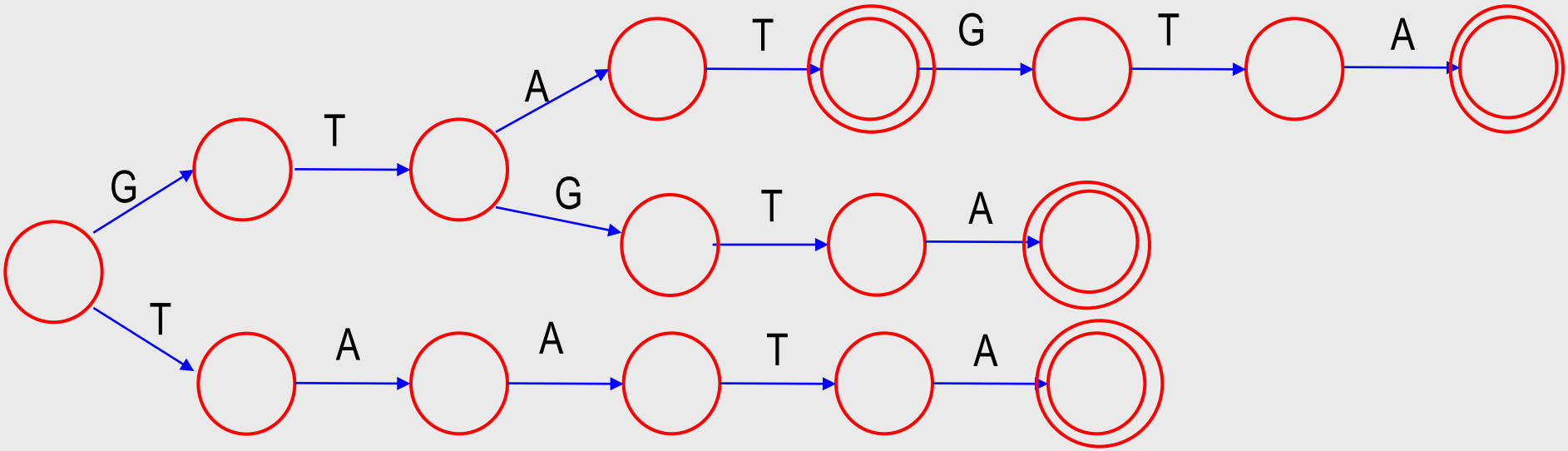
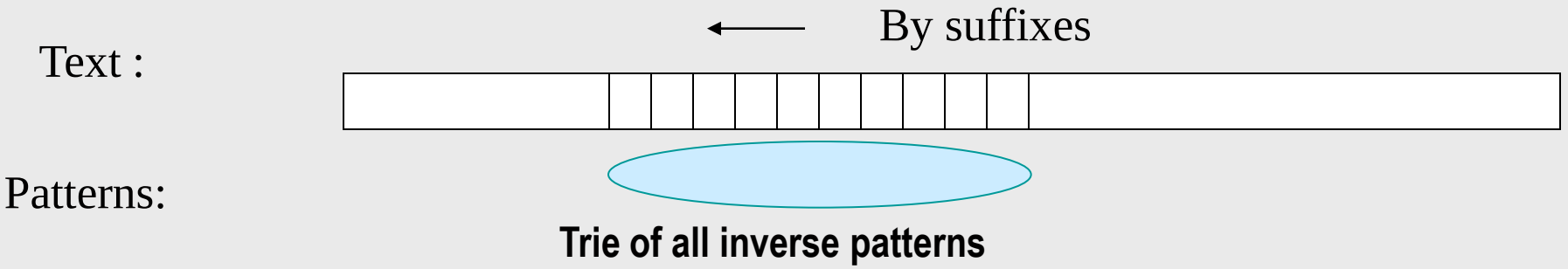


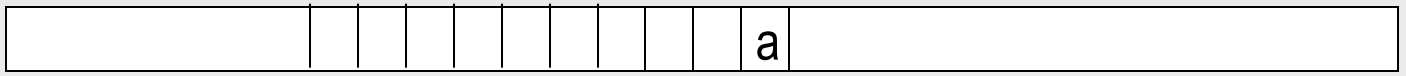
Which is the cost?

Set Horspool algorithm

- **How the comparison is made?**



- **Which is the next position of the window?**

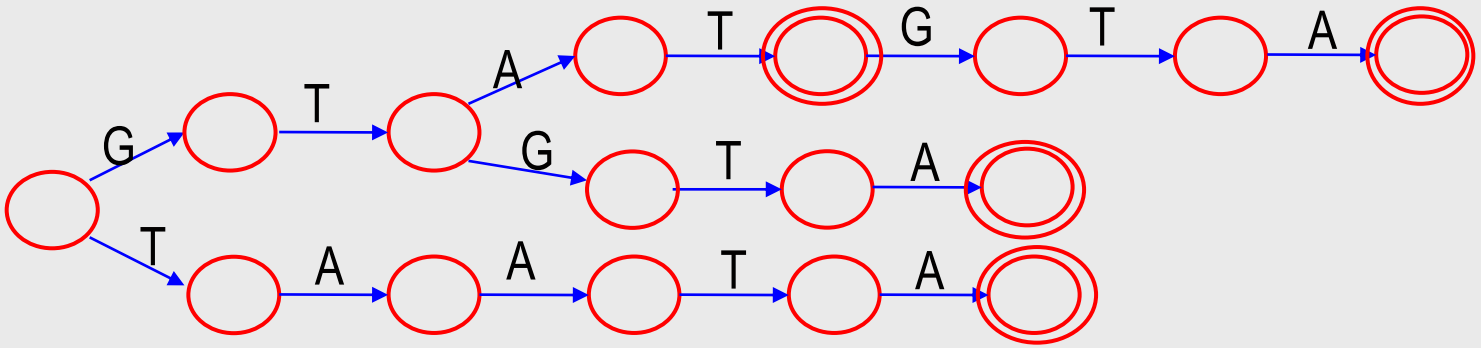


We shift until a is aligned with the first a in the trie not longer than *lmin*, or *lmin*

Set Horspool algorithm

Search for ATGTATG,TATG,ATAAT,ATGTG

1. Construct the trie of GTATGTA, GTAT, TAATA i GTGTA



2. Determine *lmin*=

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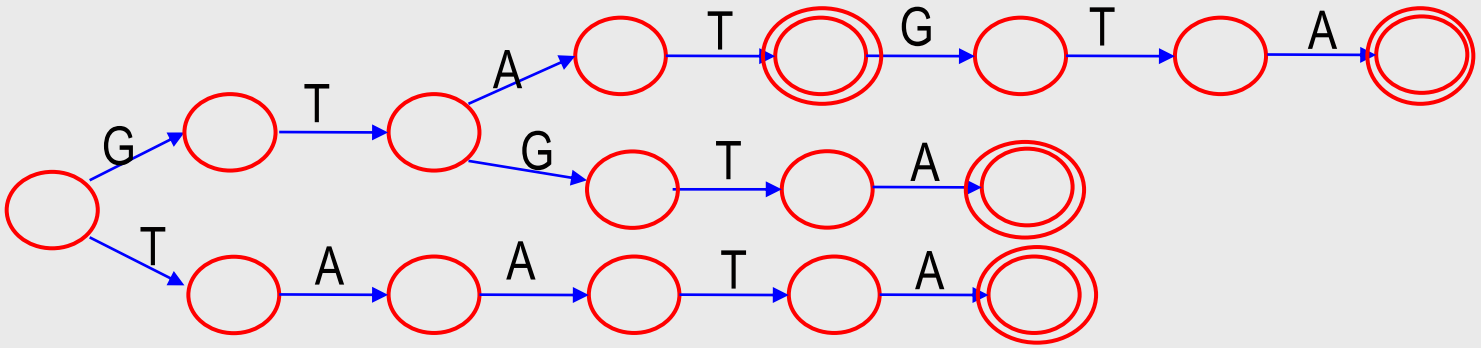

2. Determine *lmin=4*

3. Determine the shift table

A	1
C	4 (lmin)
G	
T	

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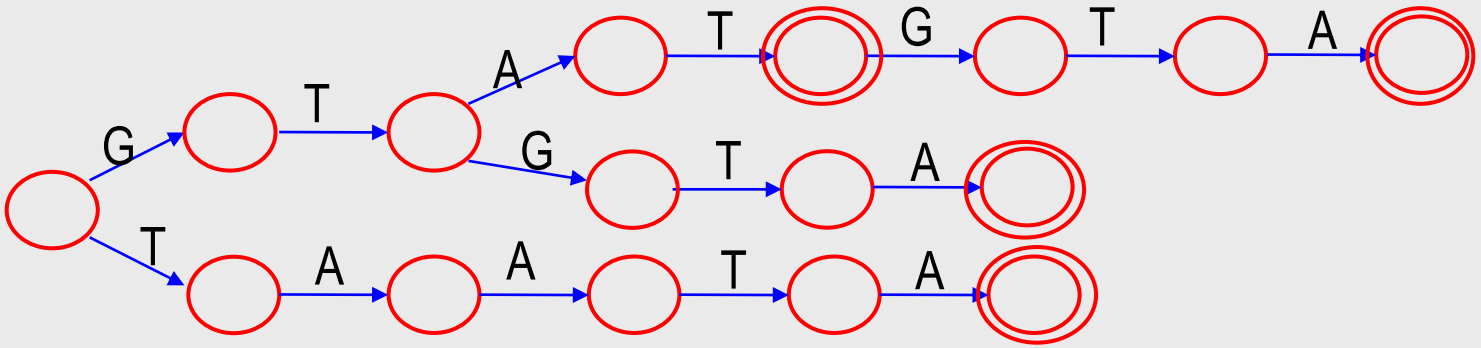

2. Determine *lmin=4*

3. Determine the shift table

A	1
C	4 (lmin)
G	2
T	

Set Horspool algorithm

Search for ATGTATG,TATG,ATAAT,ATGTG

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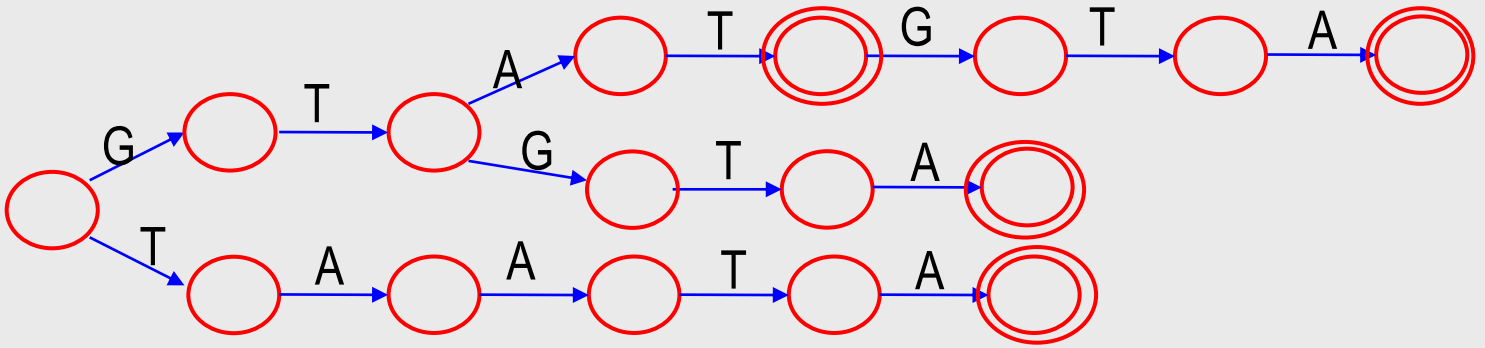


2. Determine *lmin=4*

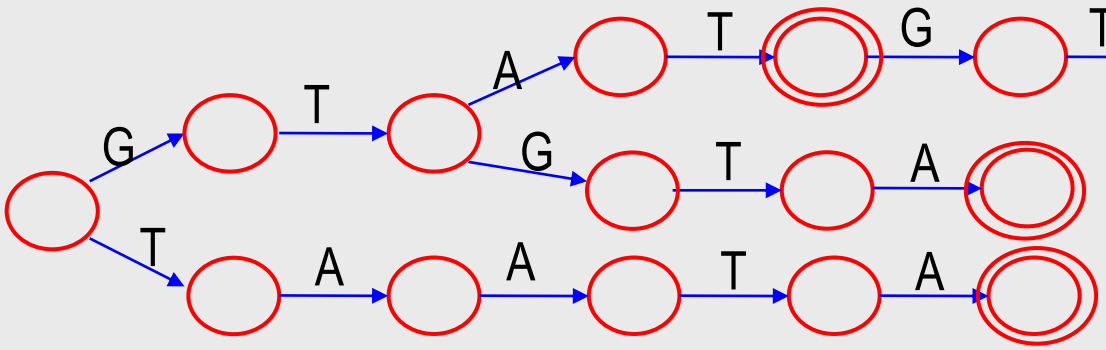
3. Determine the shift table

A	1
C	4 (lmin)
G	2
T	1

4. Find the patterns

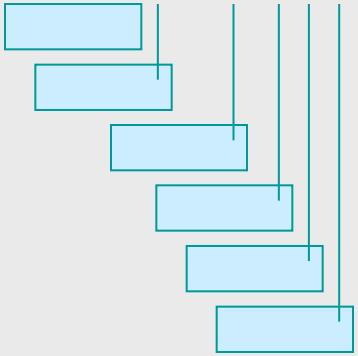
Set Horspool algorithm

Search for ATGTATG,TATG,ATAAT,ATGTG



A	1
C	4 (lmin)
G	2
T	1

text: ACATGCTATGTGACA…



Set Horspool algorithm

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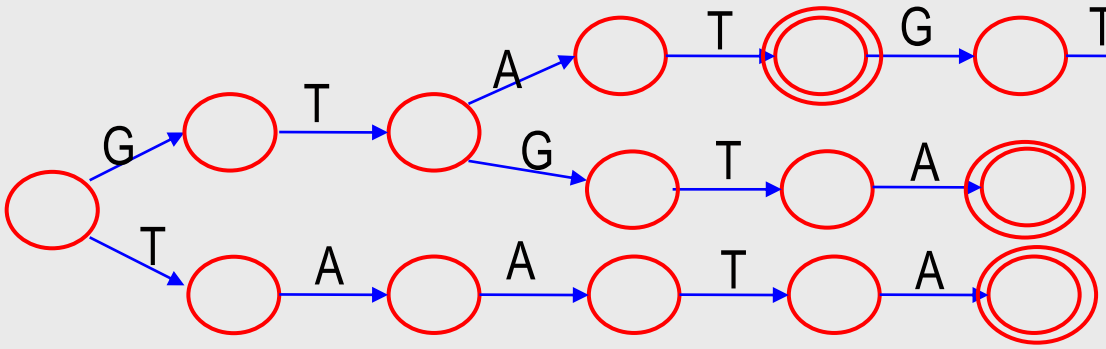

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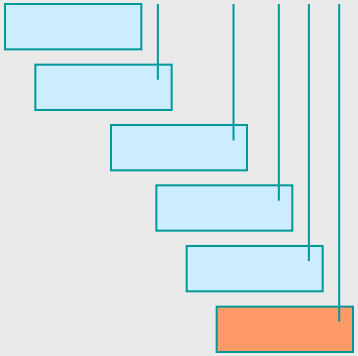

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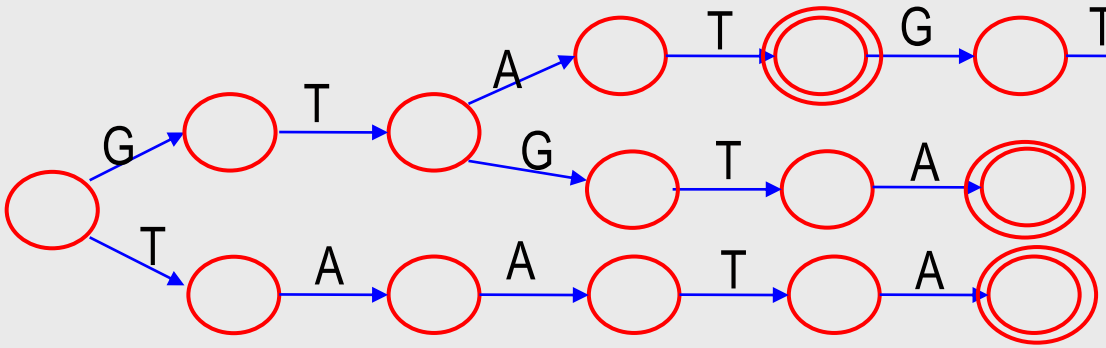

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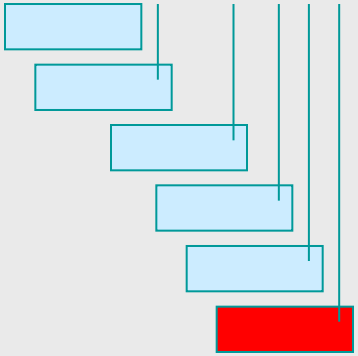

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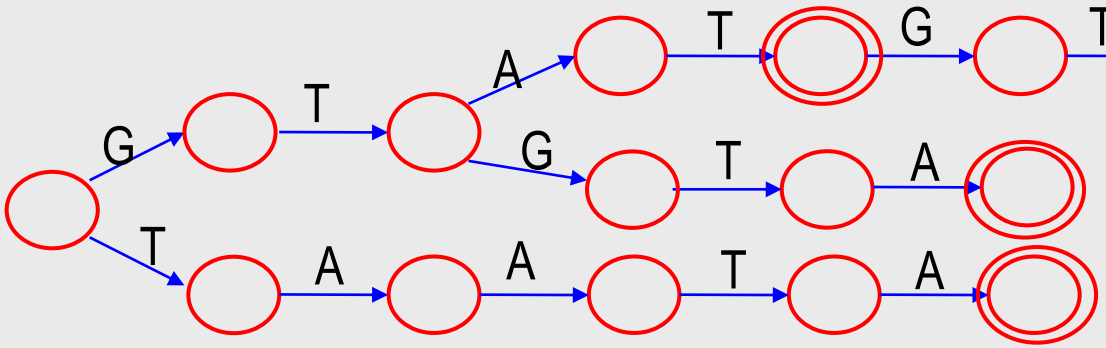

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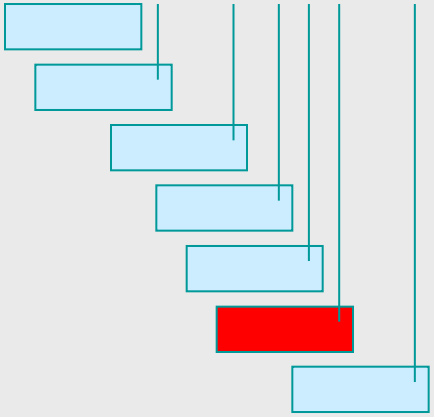

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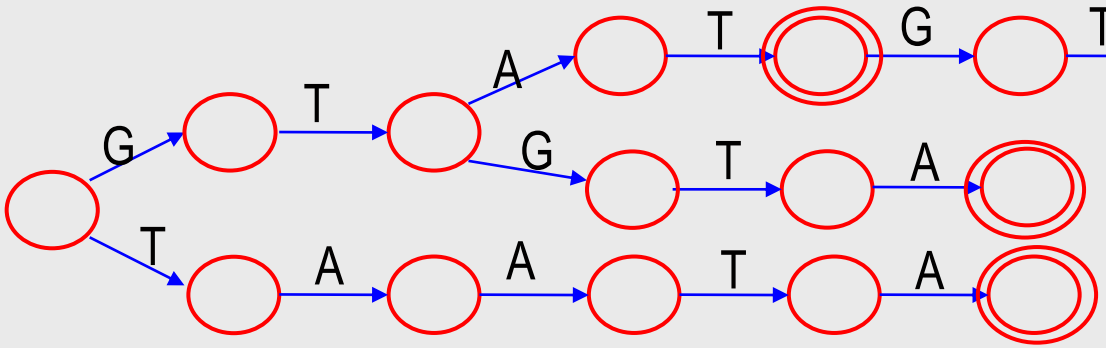

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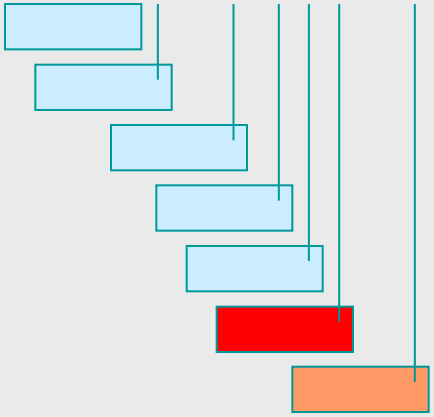

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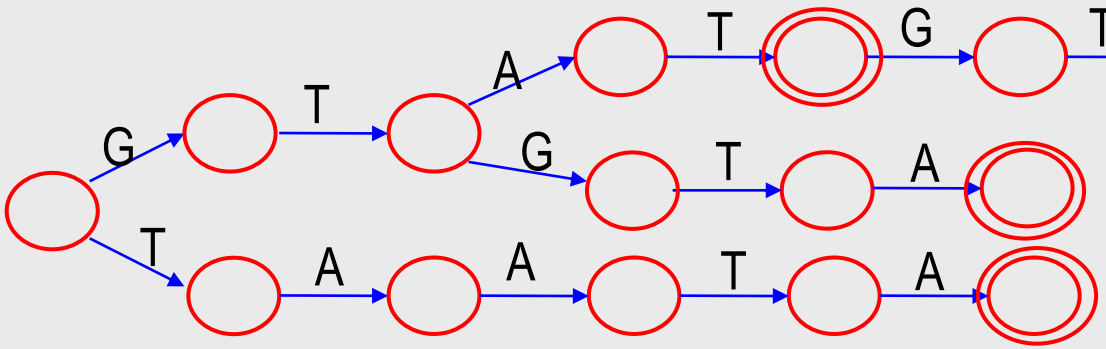

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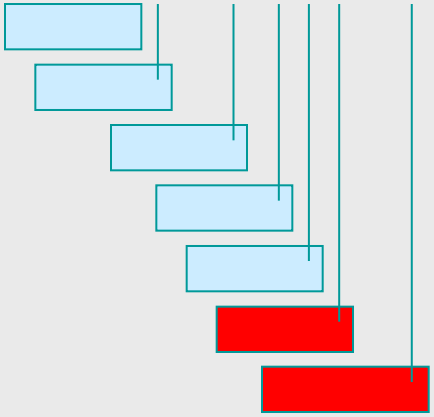

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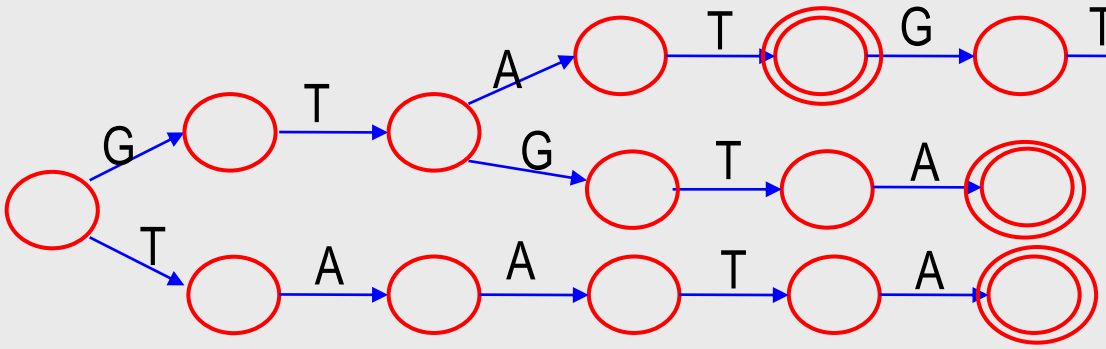

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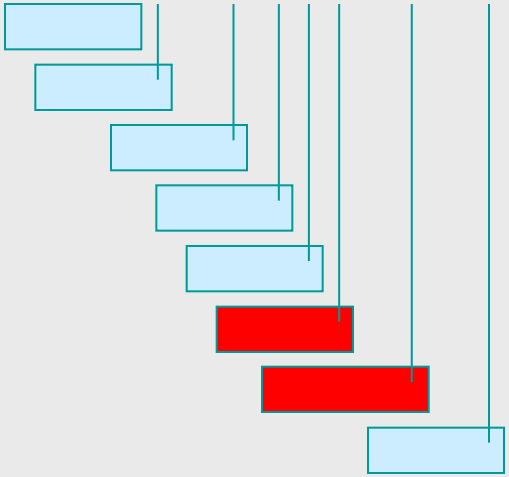

…

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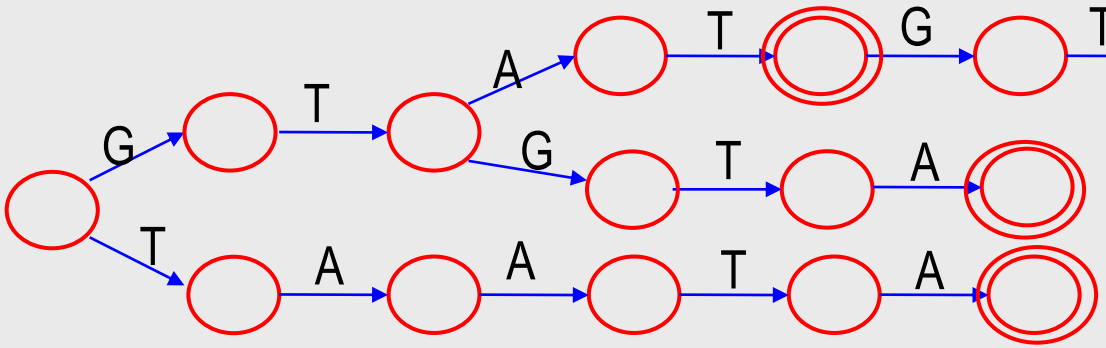

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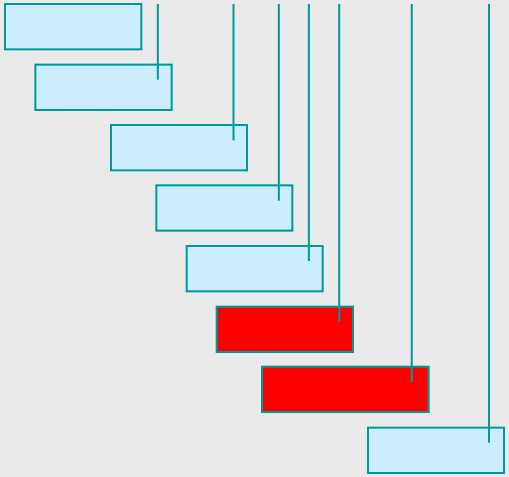

…

As more patterns we search for, shorter shifts we do!

Is the expected length of the shifts related with the number of patterns?

Set Horspool algorithm →Wu-Manber algorithm

How the length of shifts can be increased?

By reading blocks of symbols instead of only one!
Given ATGTATG,TATG,ATAAT,ATGTG

1 símbol

A	1
C	4 (lmin)
G	2
T	1

2 símbols

AA	1
AC	3 (*LMIN-L+1*)
AG	
AT	
CA	
CC	
CG	
…	

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…	

AA	1
AT	1
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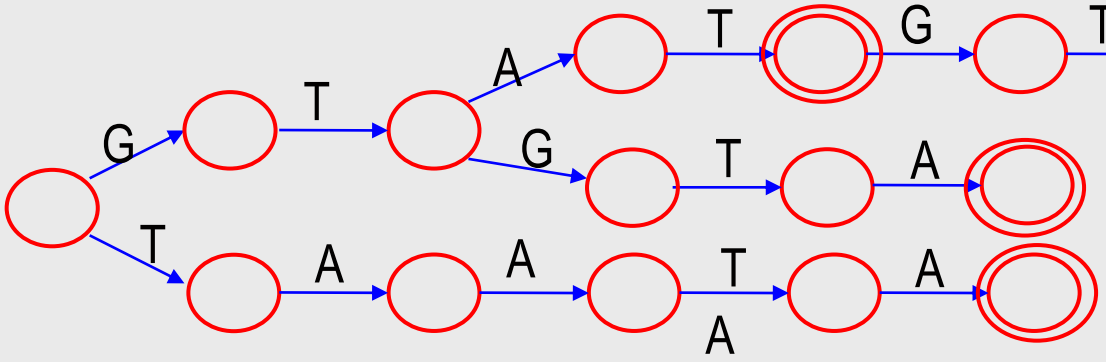
TA	2
TG	2

Wu-Manber algorithm

Search for ATGTATG,TATG,ATAAT,ATGTG



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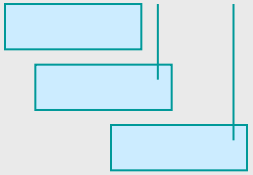

AA	1
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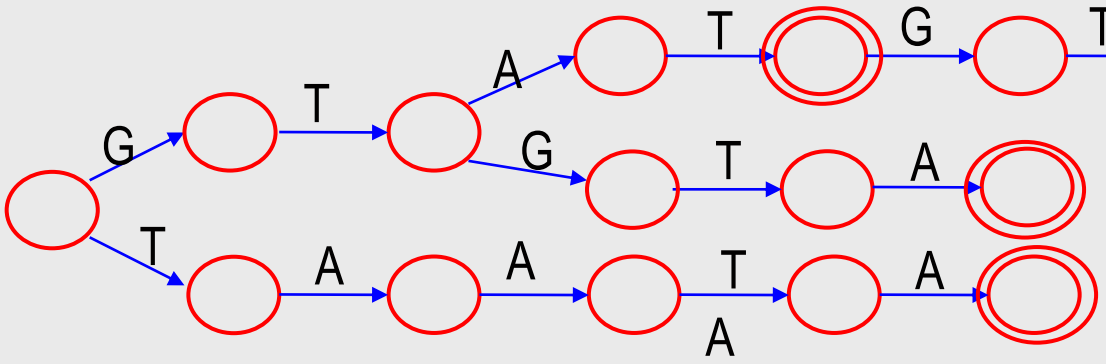
Wu-Manber algorithm

Search for ATGTATG,TATG,ATAAT,ATGTG



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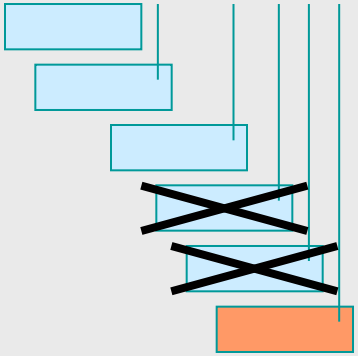

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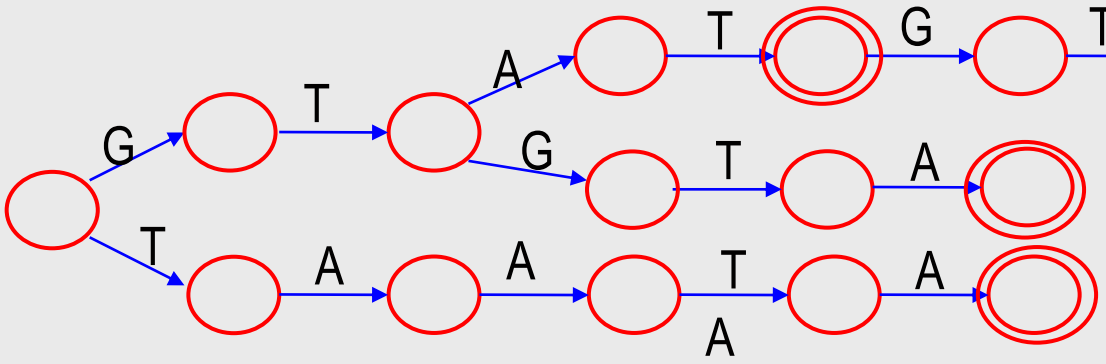

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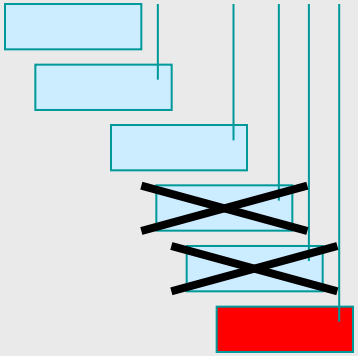

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Wu-Manber algorithm

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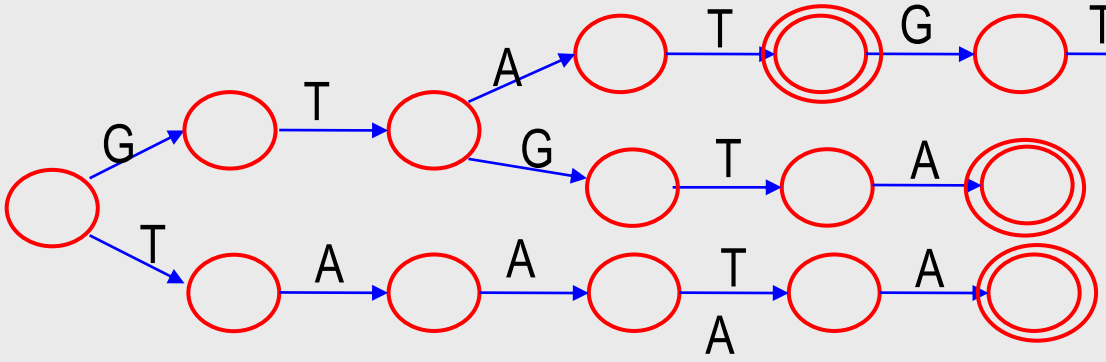

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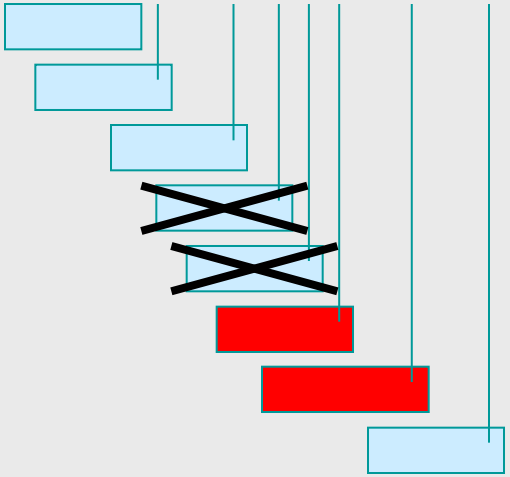
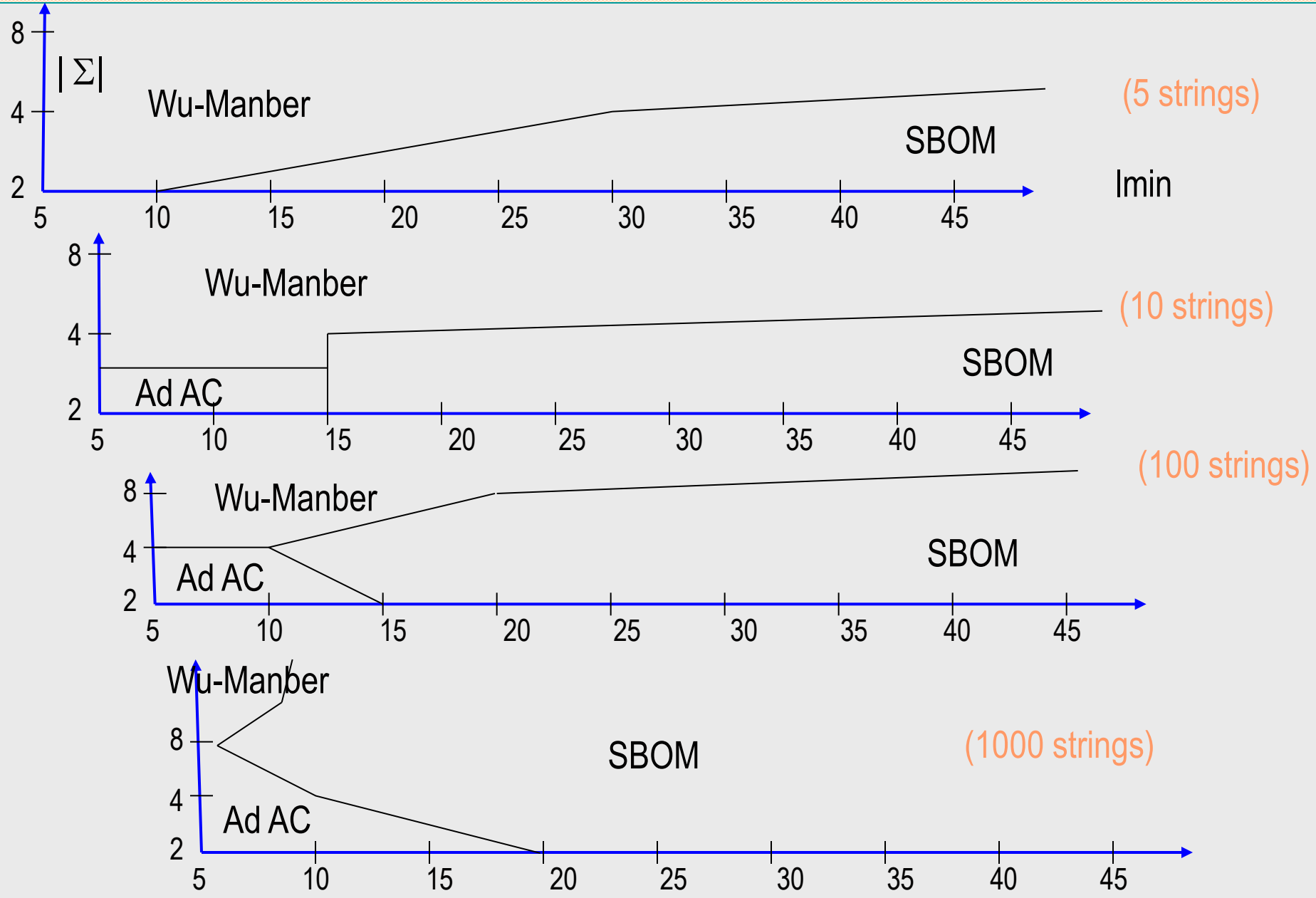


...

But given k patterns, how many symbols we should take ?

$\log_{|\Sigma|} 2*lmin*k$

Multiple string matching



BOM algorithm (Backward Oracle Matching)

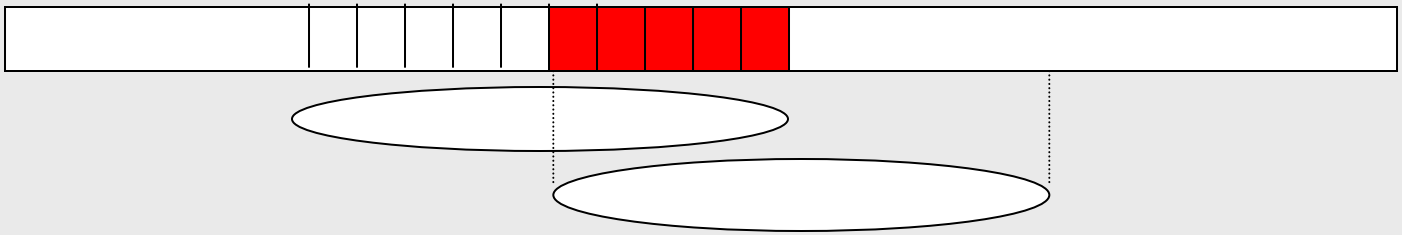
- **How the comparison is made?**

Text :

Pattern : Automata: Factor Oracle

Check if the suffix is a factor of any pattern

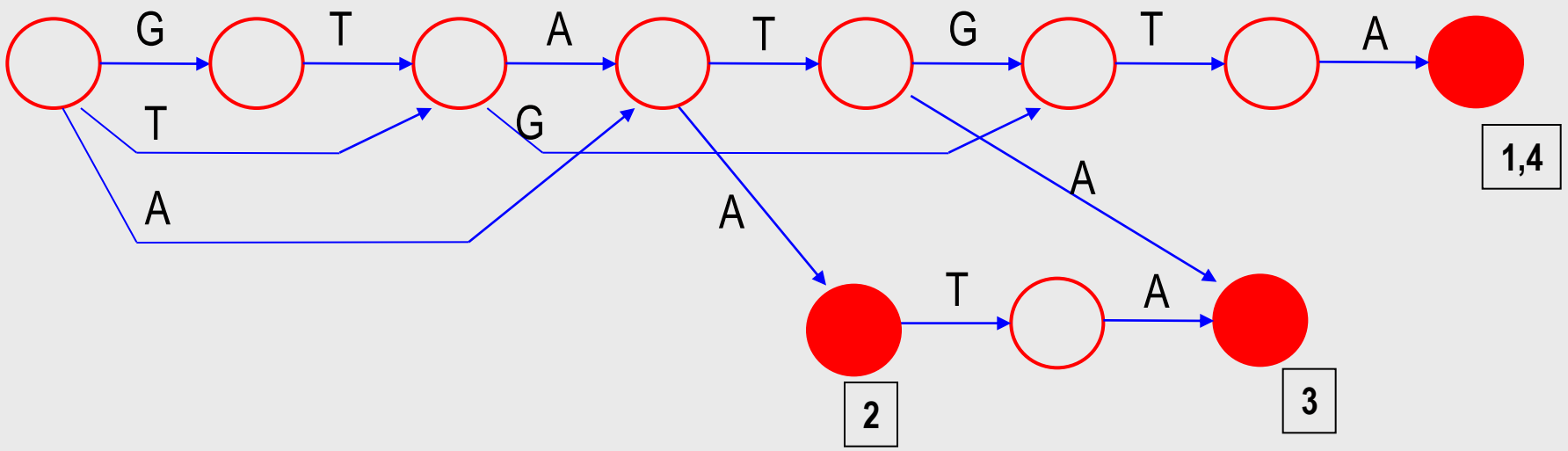
- **Which is the next position of the window?**



The position determined by the last character of the text
with a transition in the automata

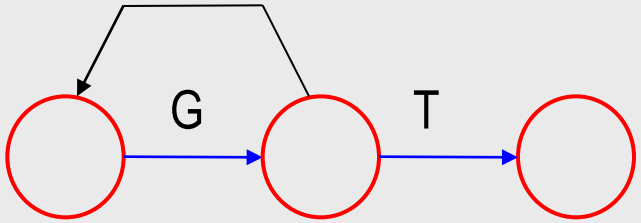
Factor Oracle of k strings

How can we build the Factor Oracle of GTATGTA, GTAA, TAATA i GTGTA ?



Factor Oracle of k strings

Given the Factor Oracle of GTATGTA



Factor Oracle of k strings

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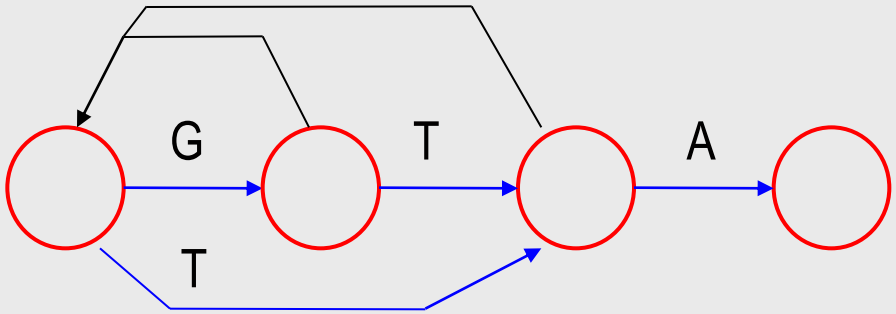

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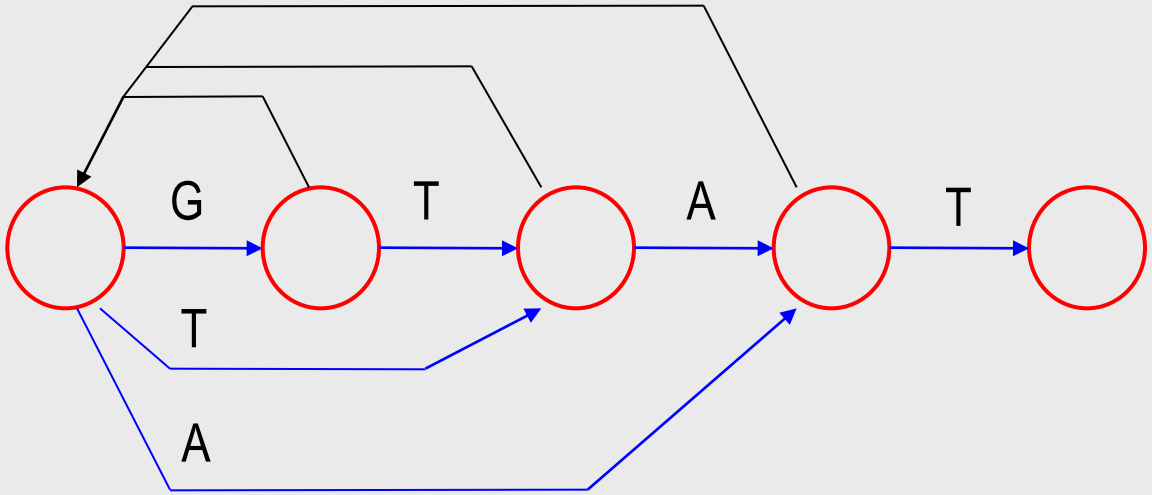
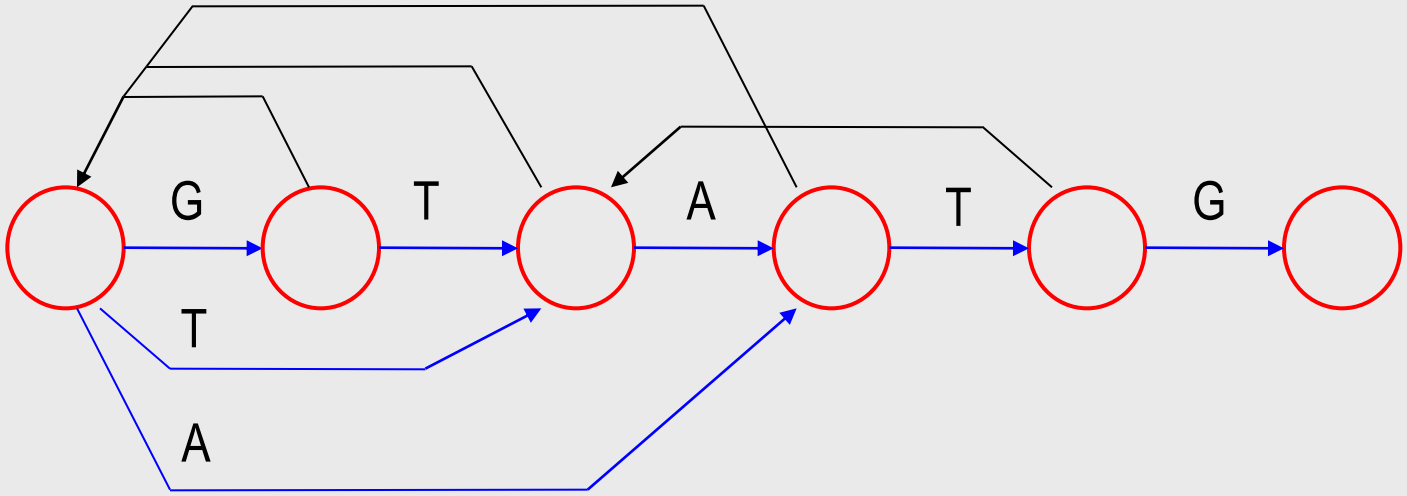


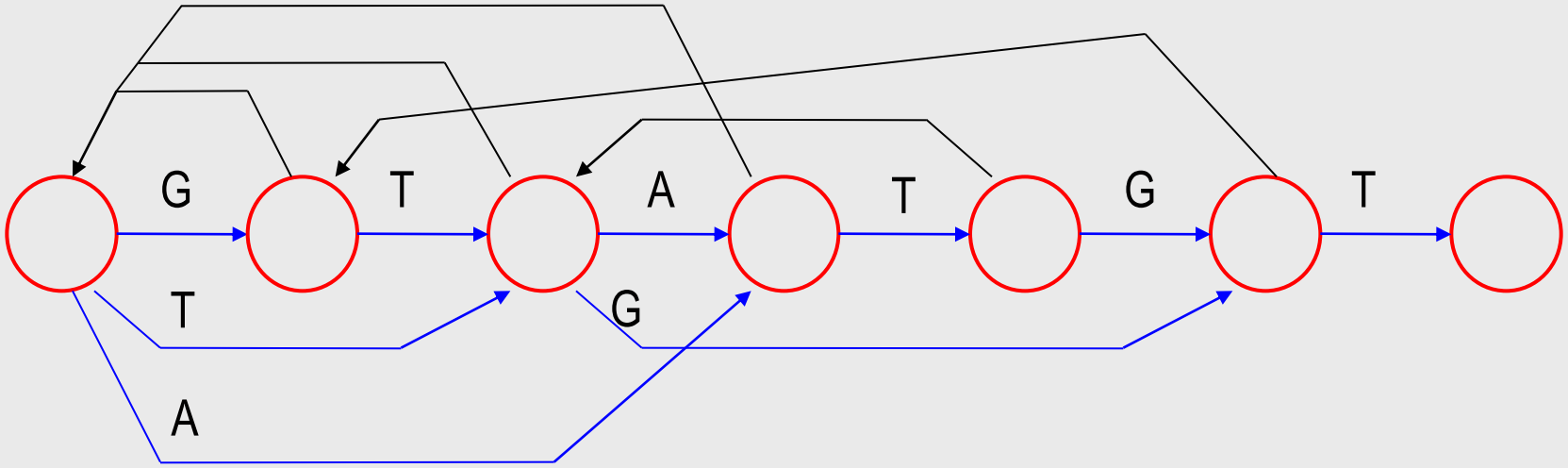
Factor Oracle of k strings

Given the Factor Oracle of GTATGTA



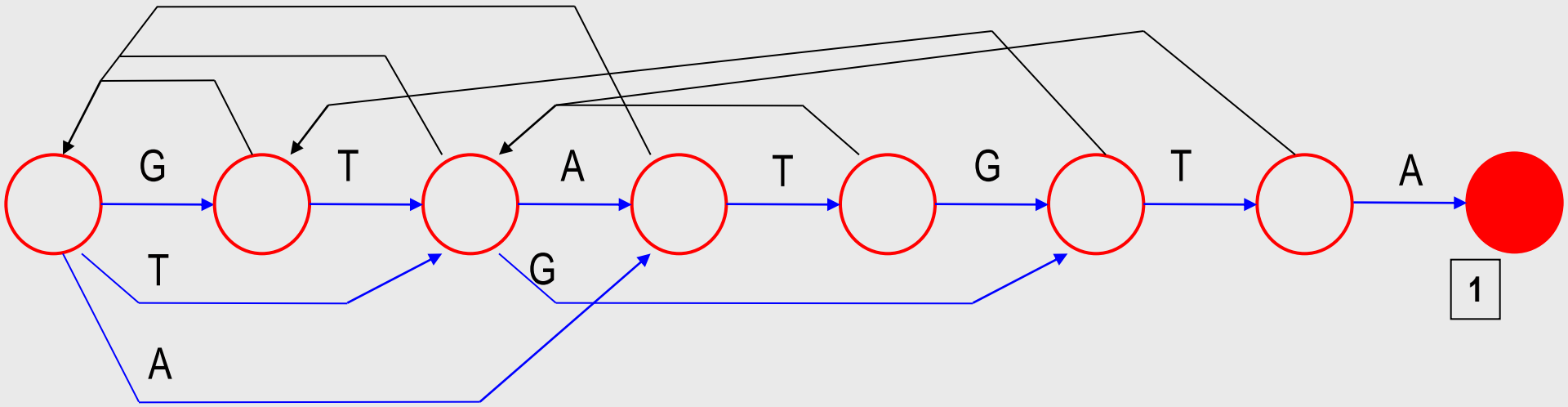
Factor Oracle of k strings

Given the Factor Oracle of GTATGTA



Factor Oracle of k strings

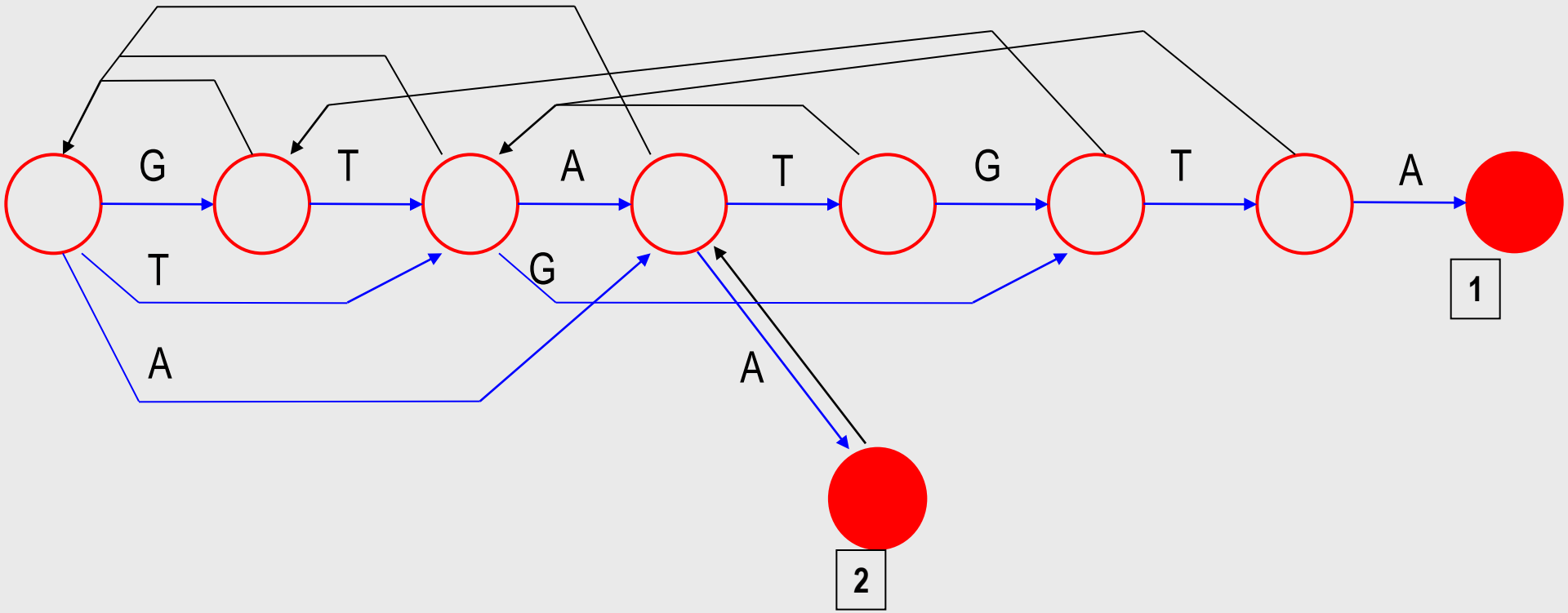
Given the Factor Oracle of GTATGTA



… we insert GTAA

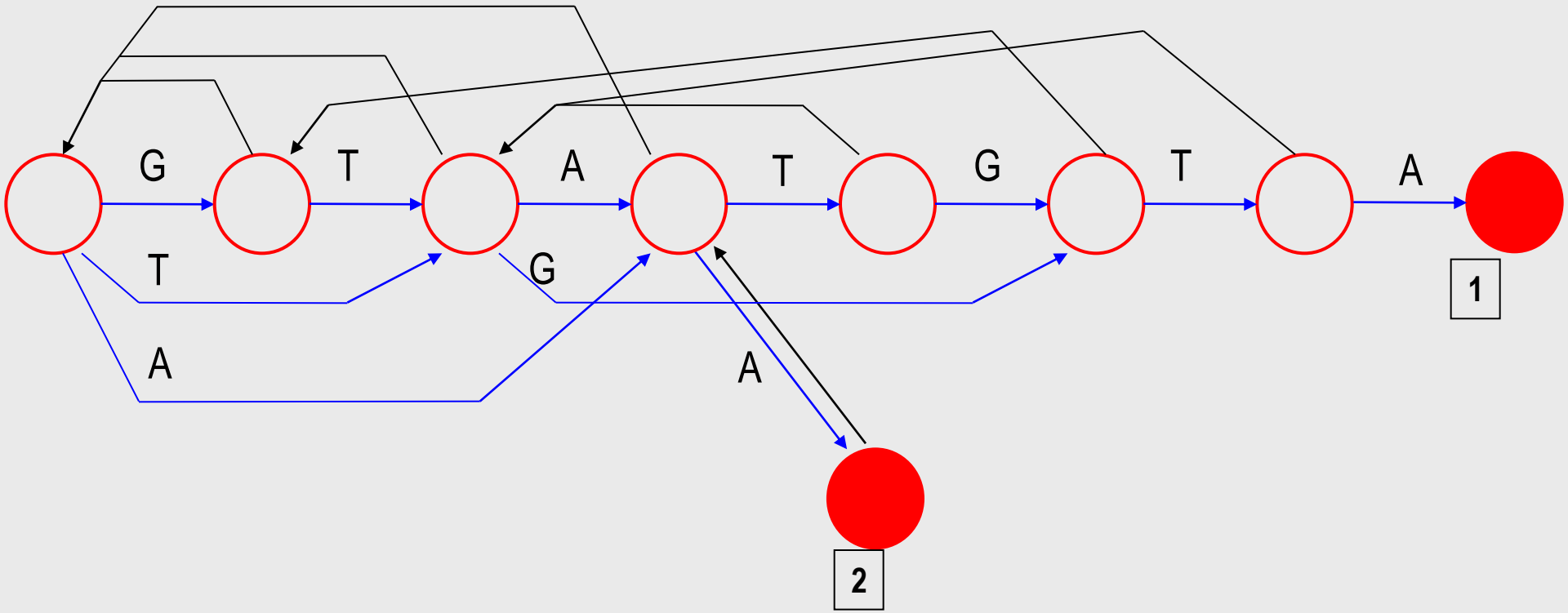
Factor Oracle of k strings

…inserting GTAA



Factor Oracle of k strings

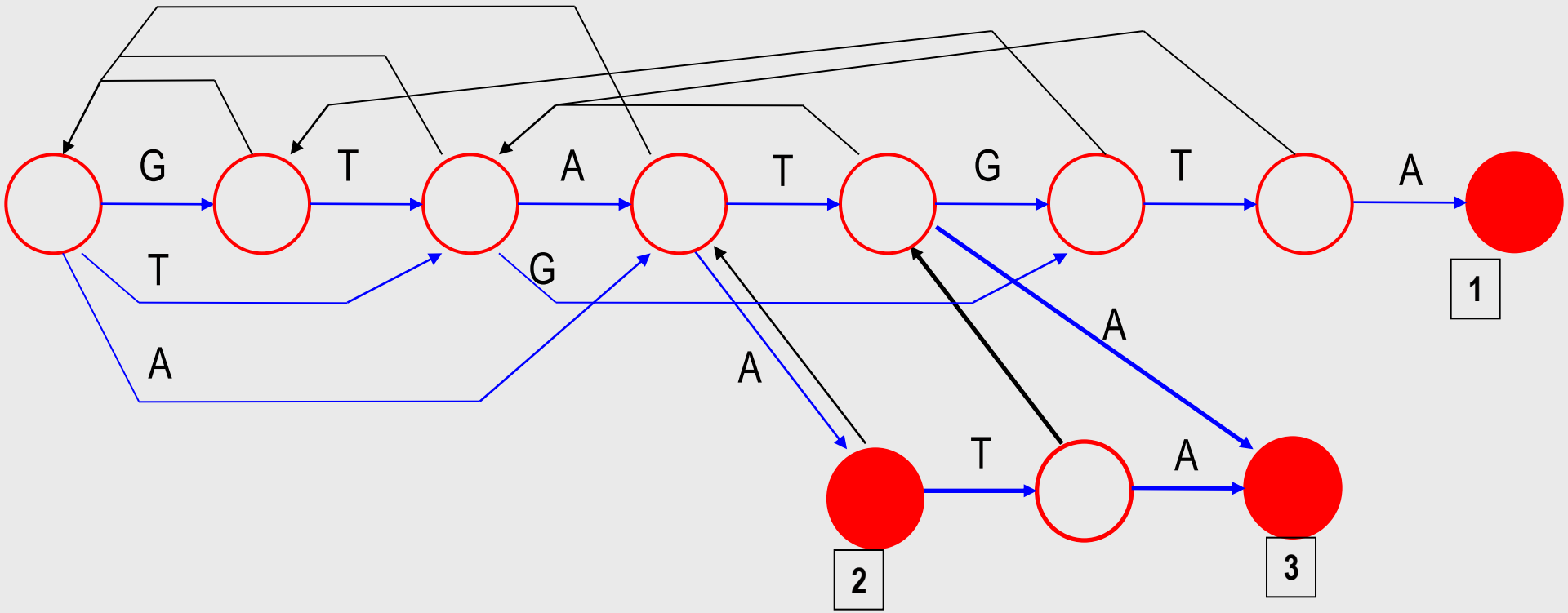
Given the AFO of GTATGTA and GTAA



… we insert TAATA

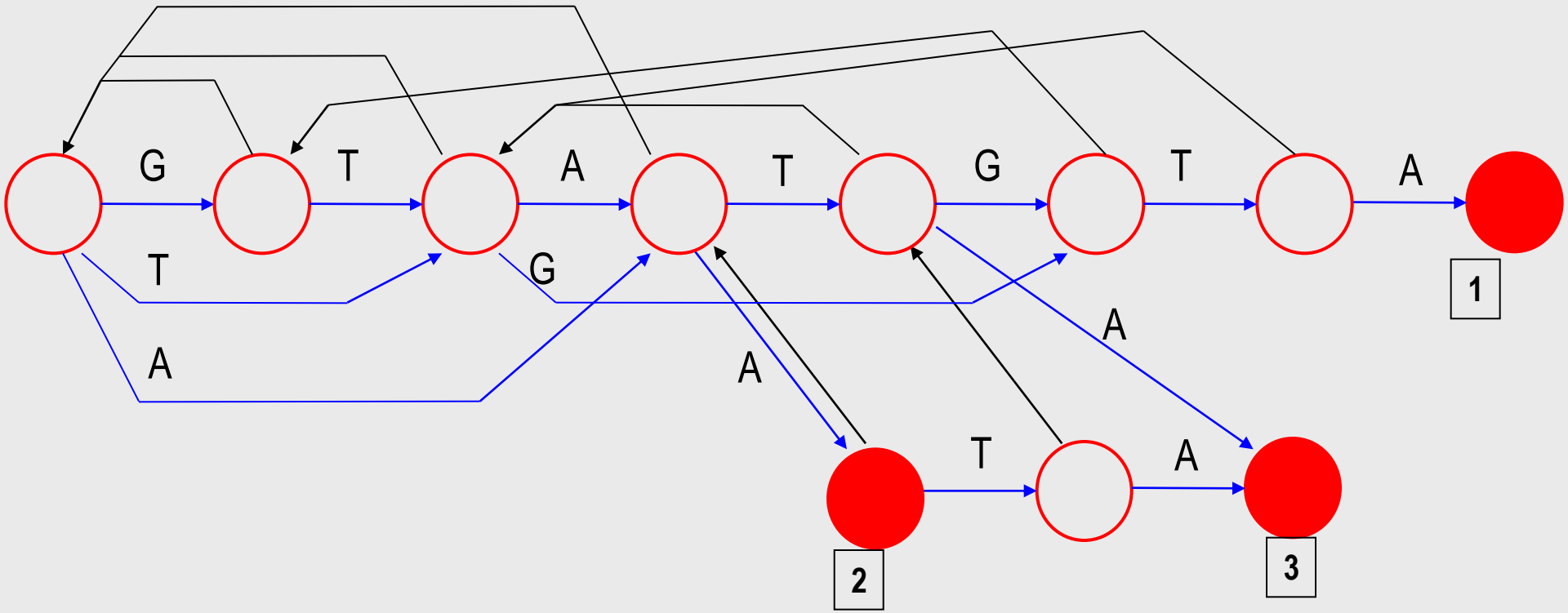
Factor Oracle of k strings

… inserting TAATA



Factor Oracle of k strings

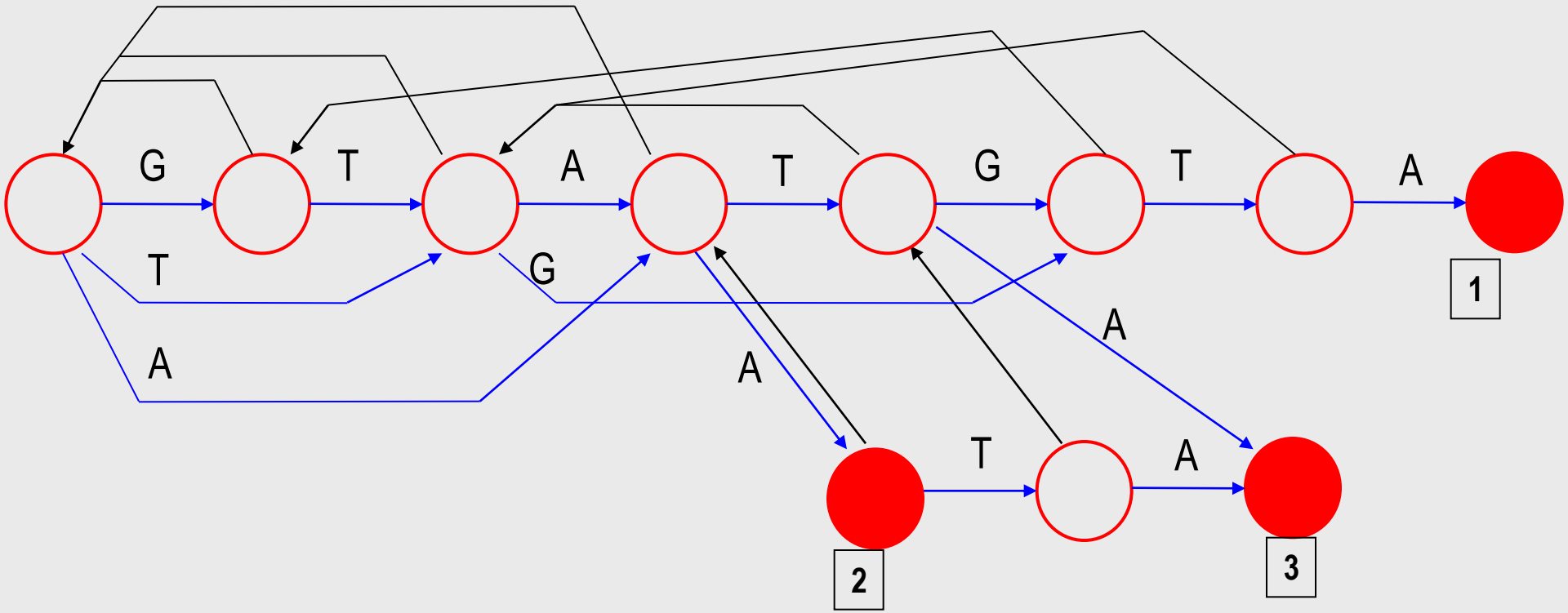
Given the AFO of GTATGTA, GTAA and TAATA



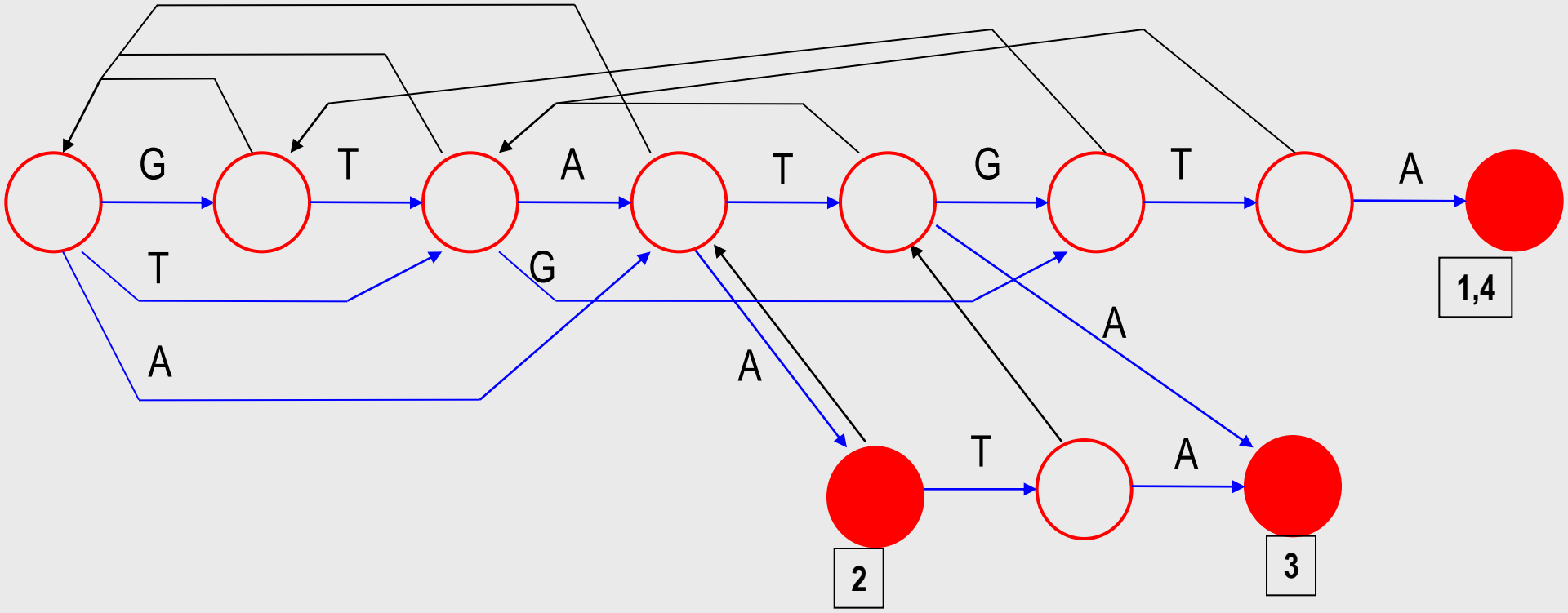
…we insert GTGTA

Factor Oracle of k strings

…inserting GTGTA



Factor Oracle of k strings



This is the Automata Factor Oracle of GTATGTA, GTAA, TAATA and GTGTA

SBOM algorithm

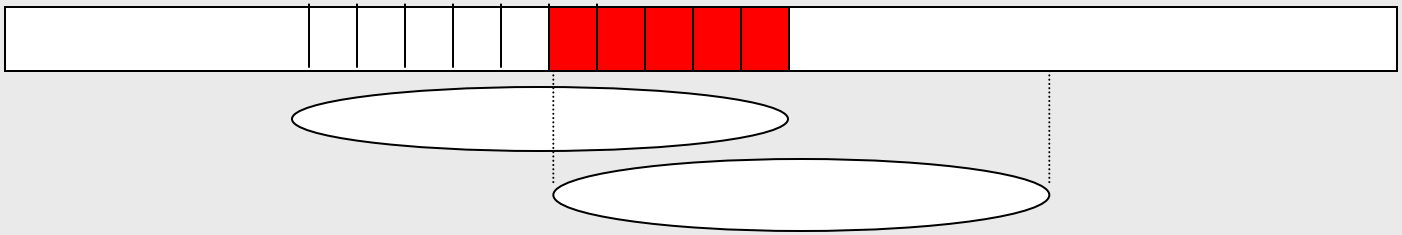
- **How the comparison is made?**

Text :

Pattern : Automata: Factor Oracle (Inverse patterns of length *lmin)*

Check if the suffix is a factor of any pattern

- **Which is the next position of the window?**

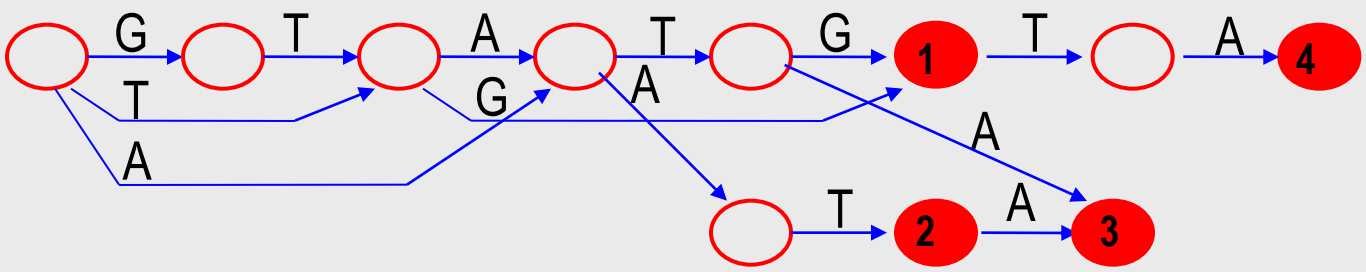


The position determined by the last character of the text
with a transition in the automata

SBOM algorithm: example

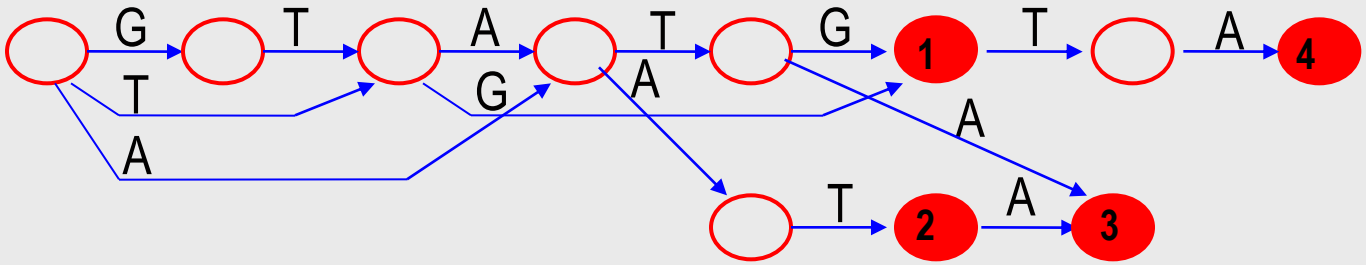
We search for the patterns
ATGTATG, TAATG,TAATAAT i AATGTG

… the we build the Automata Factor Oracle of
GTATG, GTAAT, TAATA and GTGTA
of length *lmin=5*

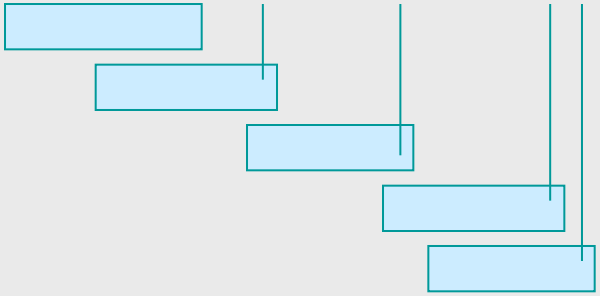


SBOM algorithm: example

Search for ATGTATG, TAATG,TAATAAT i AATGTG

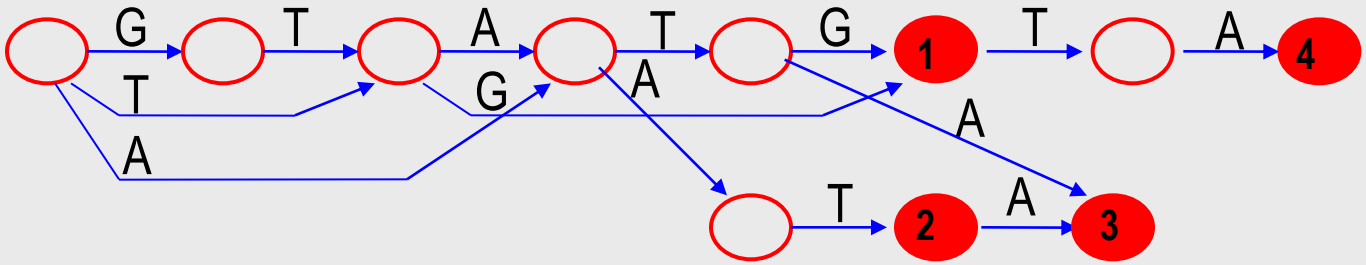


text: ACATGCTAGCTATAATAATGTATG

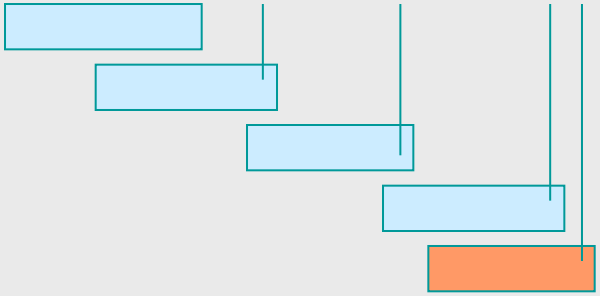


SBOM algorithm: example

Search for ATGTATG, TAATG,TAATAAT i AATGTG

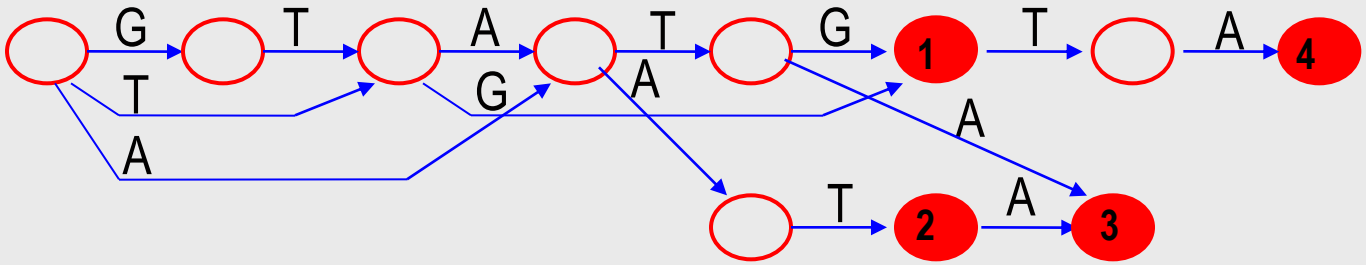


text: ACATGCTAGCTATAATAATGTATG

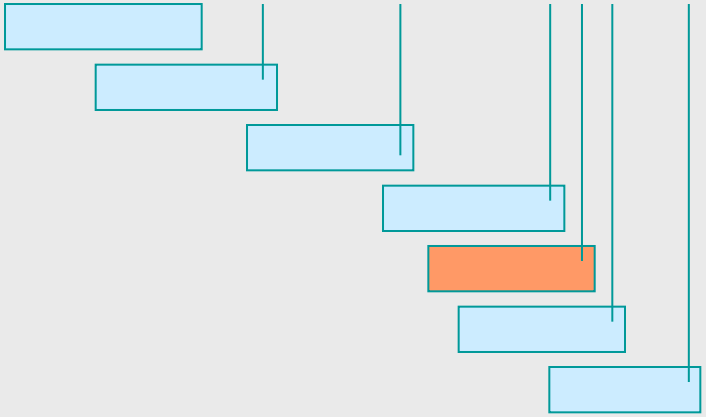


SBOM algorithm: example

Search for ATGTATG, TAATG,TAATAAT i AATGTG

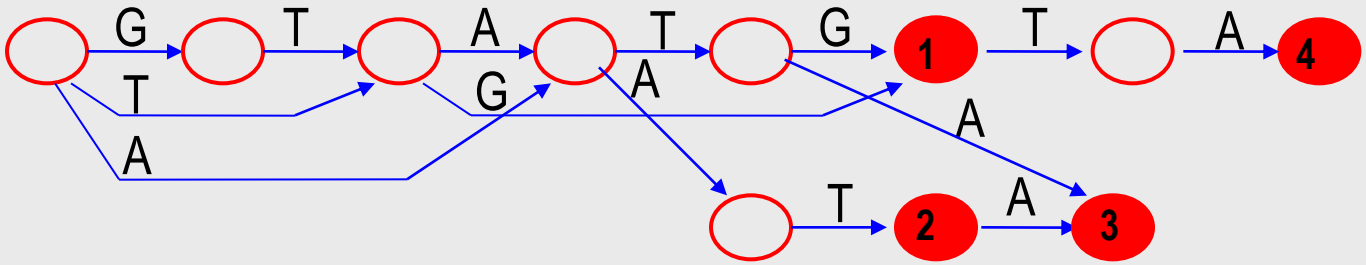


text: ACATGCTAGCTATAATAATGTATG

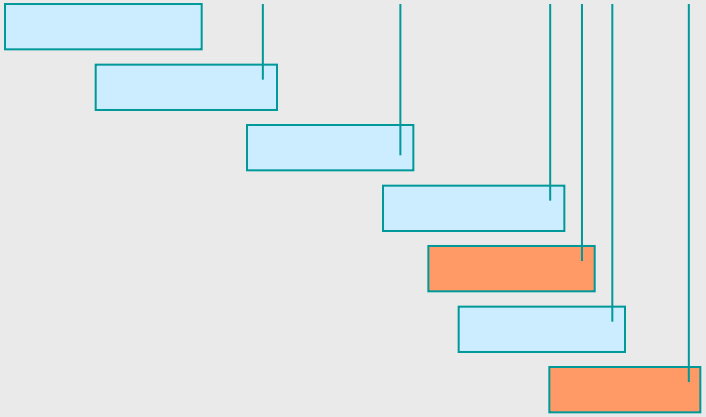


SBOM algorithm: example

Search for ATGTATG, TAATG,TAATAAT i AATGTG

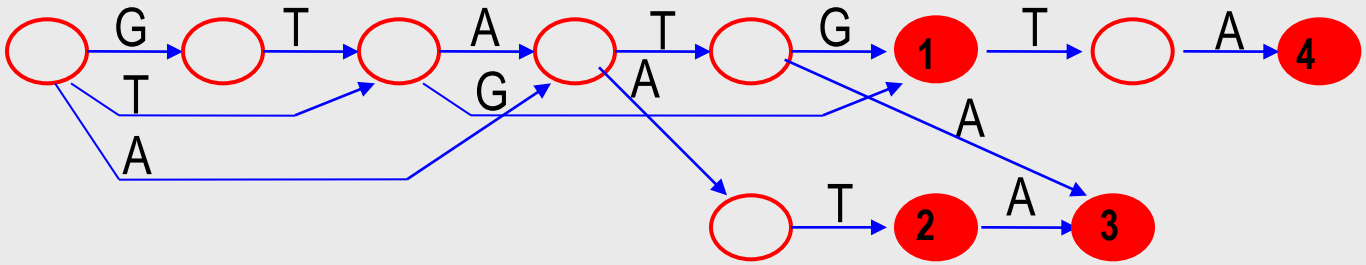


text: ACATGCTAGCTATAATAATGTATG

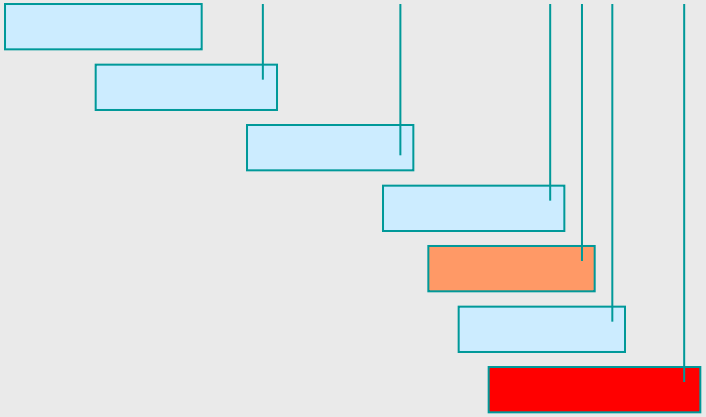


SBOM algorithm: example

Search for ATGTATG, TAATG,TAATAAT i AATGTG

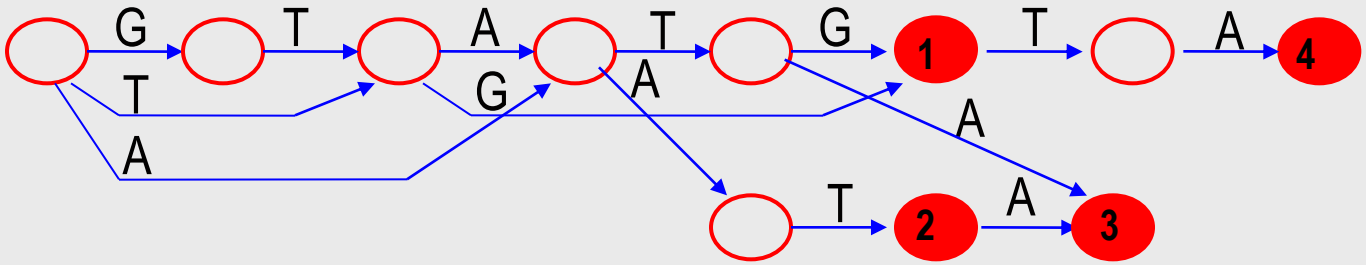


text: ACATGCTAGCTATAATAATGTATG

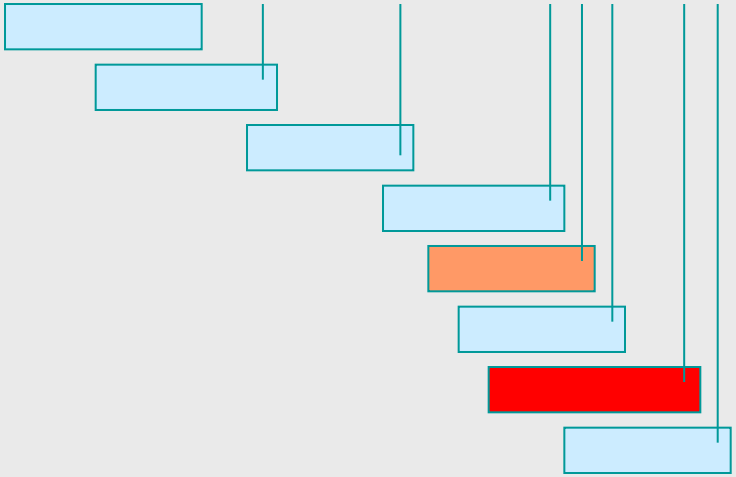


SBOM algorithm: example

Search for ATGTATG, TAATG,TAATAAT i AATGTG

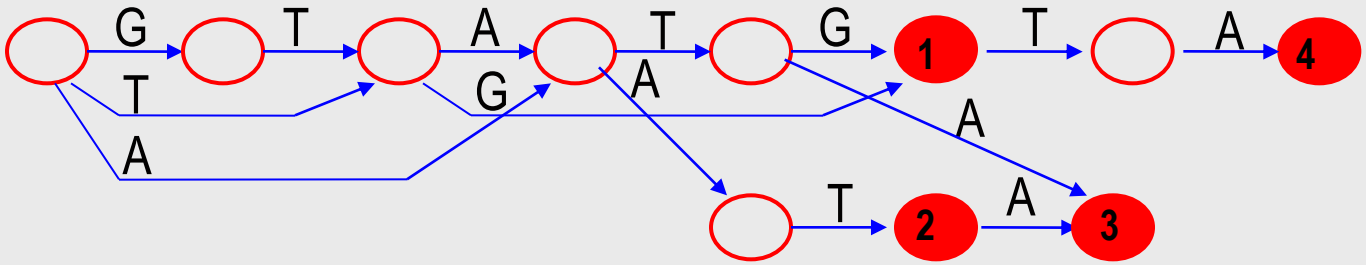


text: ACATGCTAGCTATAATAATGTATG

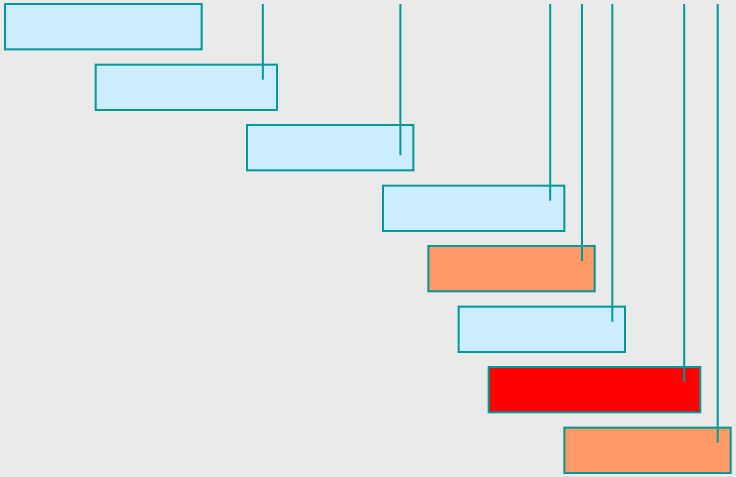


SBOM algorithm: example

Search for ATGTATG, TAATG,TAATAAT i AATGTG

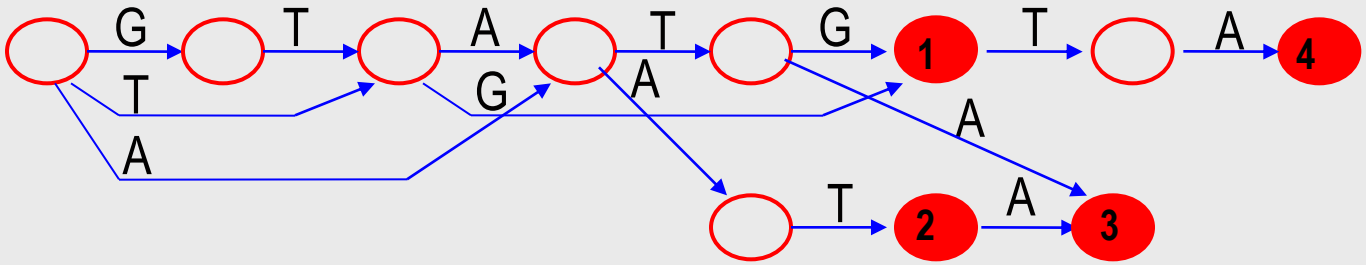


text: ACATGCTAGCTATAATAATGTATG

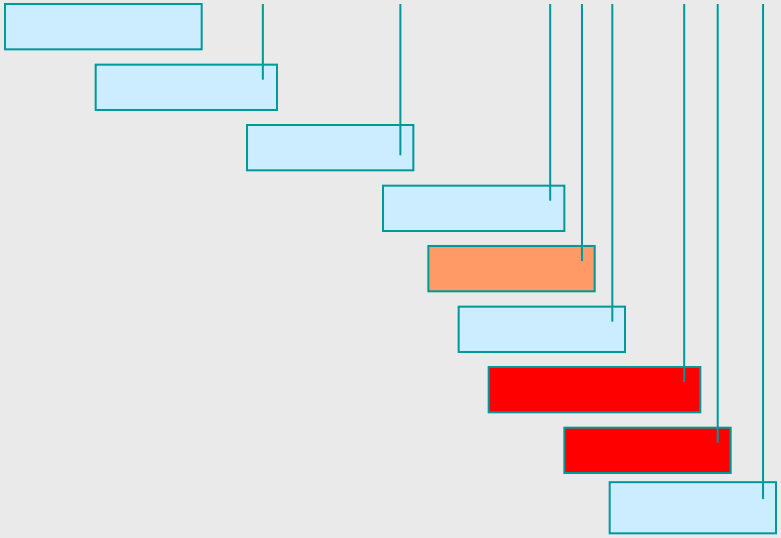


SBOM algorithm: example

Search for ATGTATG, TAATG,TAATAAT i AATGTG



text: ACATGCTAGCTATAATAATGT…



Multiple string matching