# 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

# Approximate string matching

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For instance, given the sequence

CTACTACTACGTGACTAATACTGATCGTAGCTAC…

search for the pattern ACTGA allowing one error…

… but what is the meaning of “one error”?

# Edit distance

We accept three types of errors:

1. Mismatch: ACCGTGAT ACCGAGAT
2. Insertion: ACCGTGAT ACCGATGAT
3. Deletion: ACCGTGAT ACCGGAT

} Indel

The edit distance d between two strings is the minimum number of substitutions,insertions and deletions needed to transform the first string into the second one

d(ACT,ACT)= d(ACT,AC)= d(ACT,C)=
d(ACT,)= d(AC,ATC)= d(ACTTG,ATCTG)=

# Edit distance

We accept three types of errors:

1. Mismatch: ACCGTGAT ACCGAGAT
2. Insertion: ACCGTGAT ACCGATGAT
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} Indel

The edit distance d between two strings is the minimum number of substitutions,insertions and deletions needed to transform the first string into the second one

d(ACT,ACT)= 0 d(ACT,AC)= 1 d(ACT,C)= 2
d(ACT,)= 3 d(AC,ATC)= 1 d(ACTTG,ATCTG)= 2

# Edit distance and alignment of strings

The Edit distance is related with the best alignment of strings

Given

d(ACT,ACT)=0 d(ACT,AC)=1 d(ACTTG,ATCTG)=2

which is the best alignment in every case?

- ACT and ACT : ACT
  ACT
- ACT and AT: ACT
  A -T
- ACTTG and ATCTG: ACTTG ACT - TG
  ATCTG A - TCTG

Then, the alignment suggest the substitutions, insertions and deletions to transform one string into the other

# Edit distance and alignment of strings

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But which is the distance between the strings

ACGCTATGCTATACG and ACGGTAGTGACGC?

… and the best alignment between them?

1966 was the first time this problem was discussed…

and the algorithm was proposed in 1968,1970,…

using the technique called “Dynamic programming”

# Edit distance and alignment of strings

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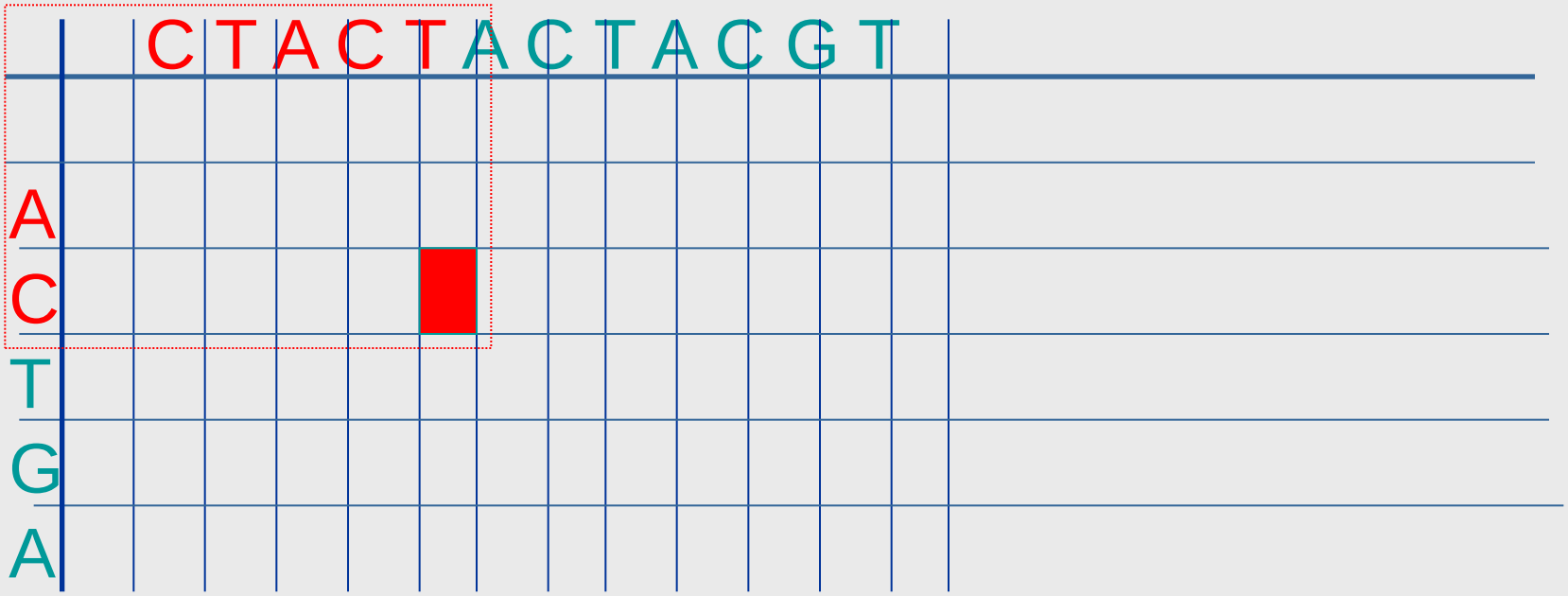
# Edit distance and alignment of strings




The cell contains the distance between AC and CTACT.

# Edit distance and alignment of strings

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# Edit distance and alignment of strings

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| | | C | T | A | C | T | A | C | T | A | C | G | T | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | ? | | | | | | | | | | | | |
| A | | | | | | | | | | | | | | |
| C | | | | | | | | | | | | | | |
| T | | | | | | | | | | | | | | |
| G | | | | | | | | | | | | | | |
| A | | | | | | | | | | | | | | |

# Edit distance and alignment of strings


-

C

# Edit distance and alignment of strings

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- -

CT

# Edit distance and alignment of strings

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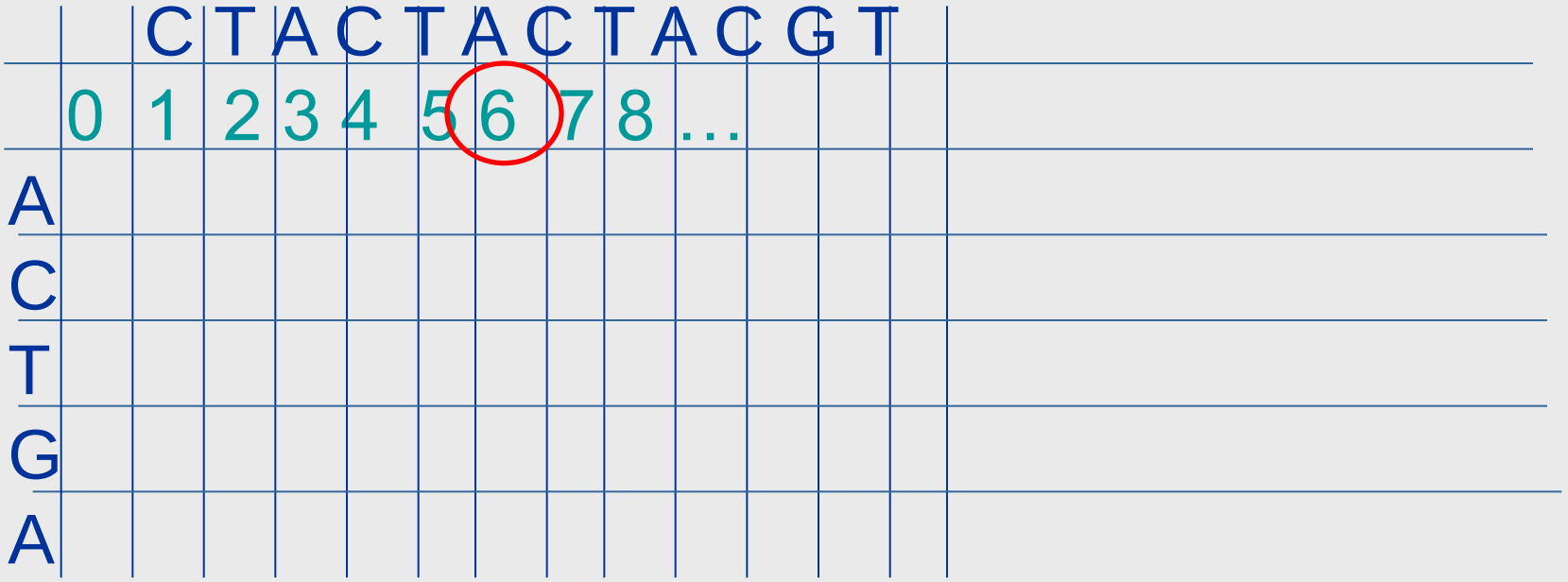


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CTACTA

# Edit distance and alignment of strings

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| | | C | T | A | C | T | A | C | T | A | C | G | T | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | ... | | | | |
| A | ? | | | | | | | | | | | | | |
| C | ? | | | | | | | | | | | | | |
| T | ? | | | | | | | | | | | | | |
| G | | | | | | | | | | | | | | |
| A | | | | | | | | | | | | | | |

# Edit distance and alignment of strings

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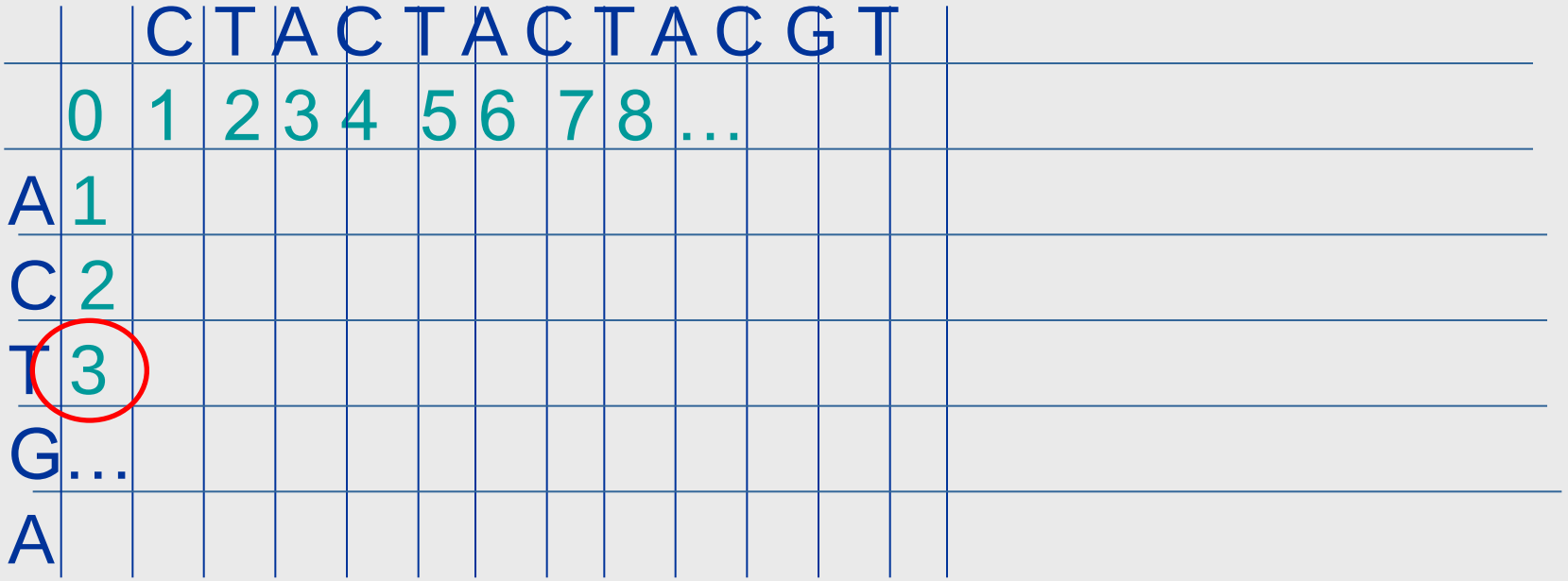
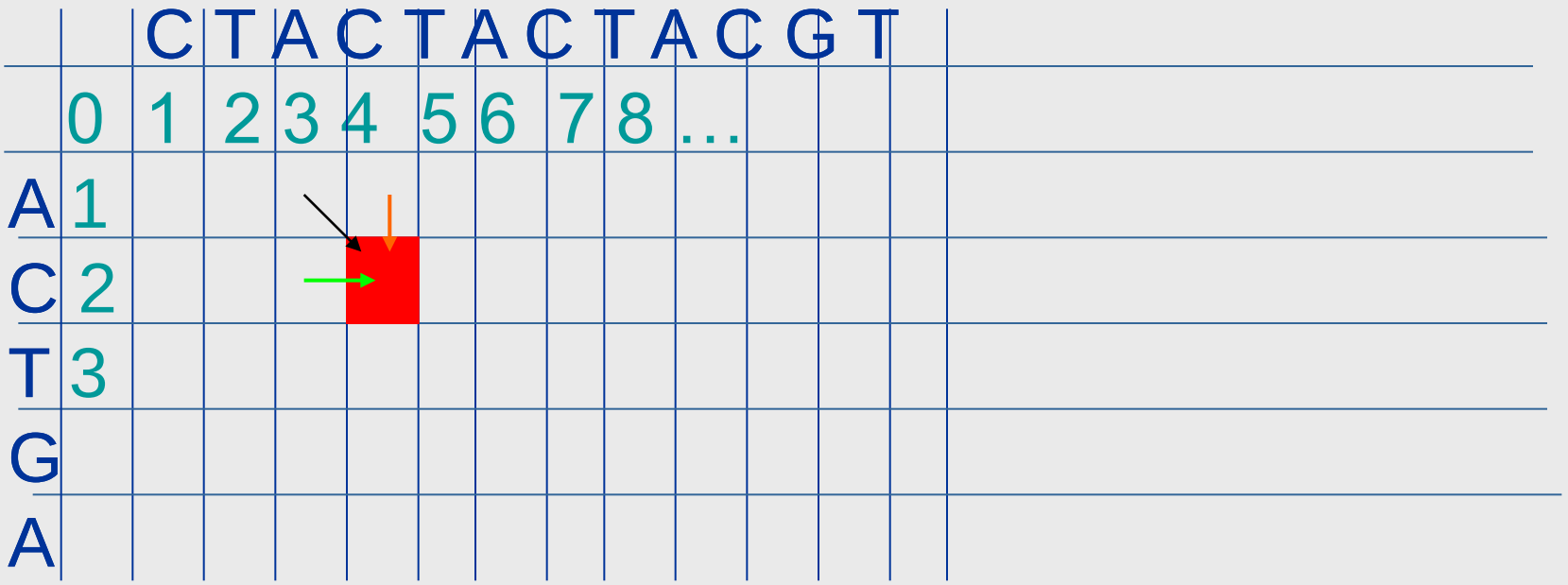



ACT

- - -

# Edit distance and alignment of strings




BA(AC,CTAC)= best

d(AC,CTAC)=min

- BA(AC,CTA) + C → d(AC,CTA)+1
- BA(A,CTA) + C C → d(A,CTA)
- BA(A,CTAC) + C - → d(A,CTAC)+1

# Edit distance and alignment of strings

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Connect to

http://alggen.lsi.upc.es/docencia/ember/leed/Tfc1.htm

and use the global method.

# Edit distance and alignment of strings

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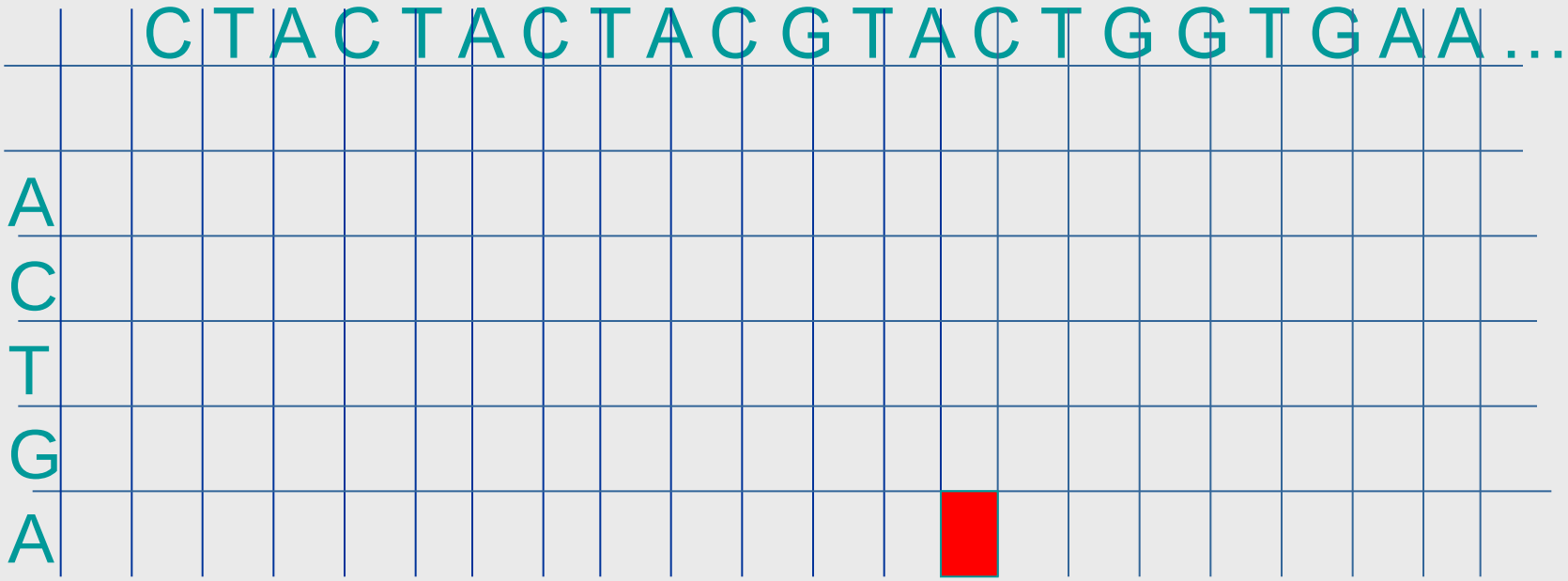
How this algorithm can be applied

to the approximate search?

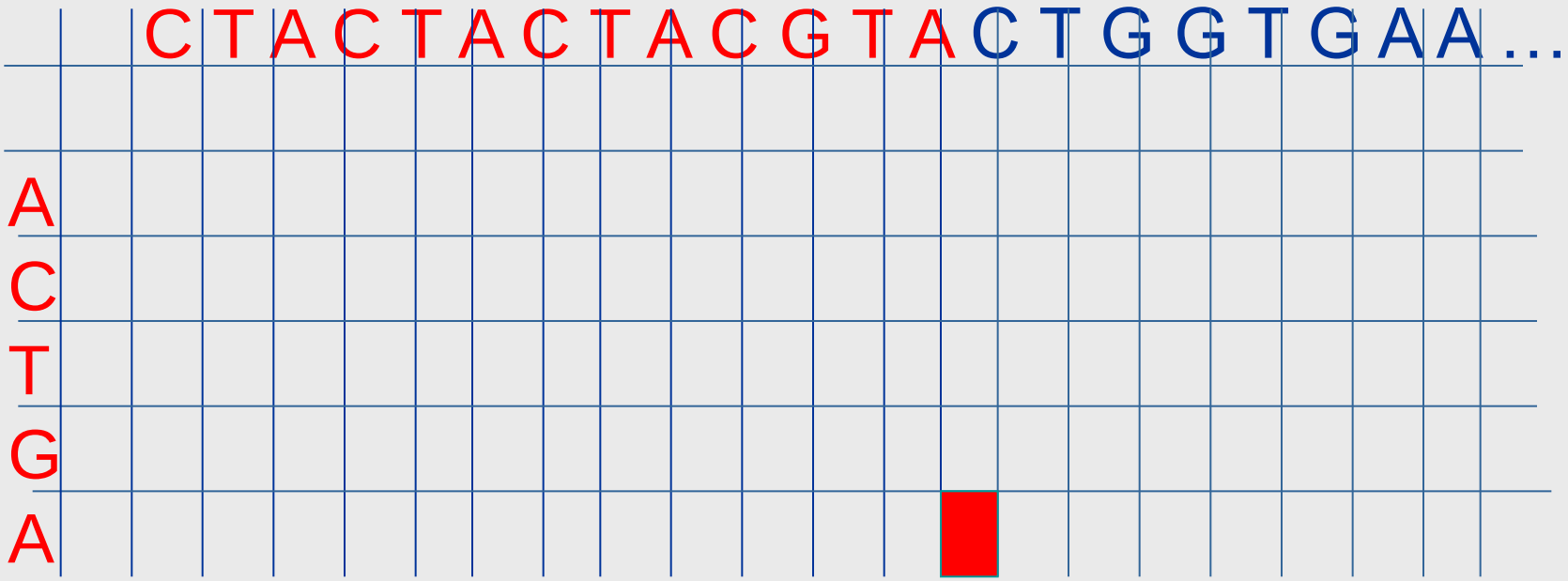
to the K-approximate string searching?

# K-approximate string searching




This cell …

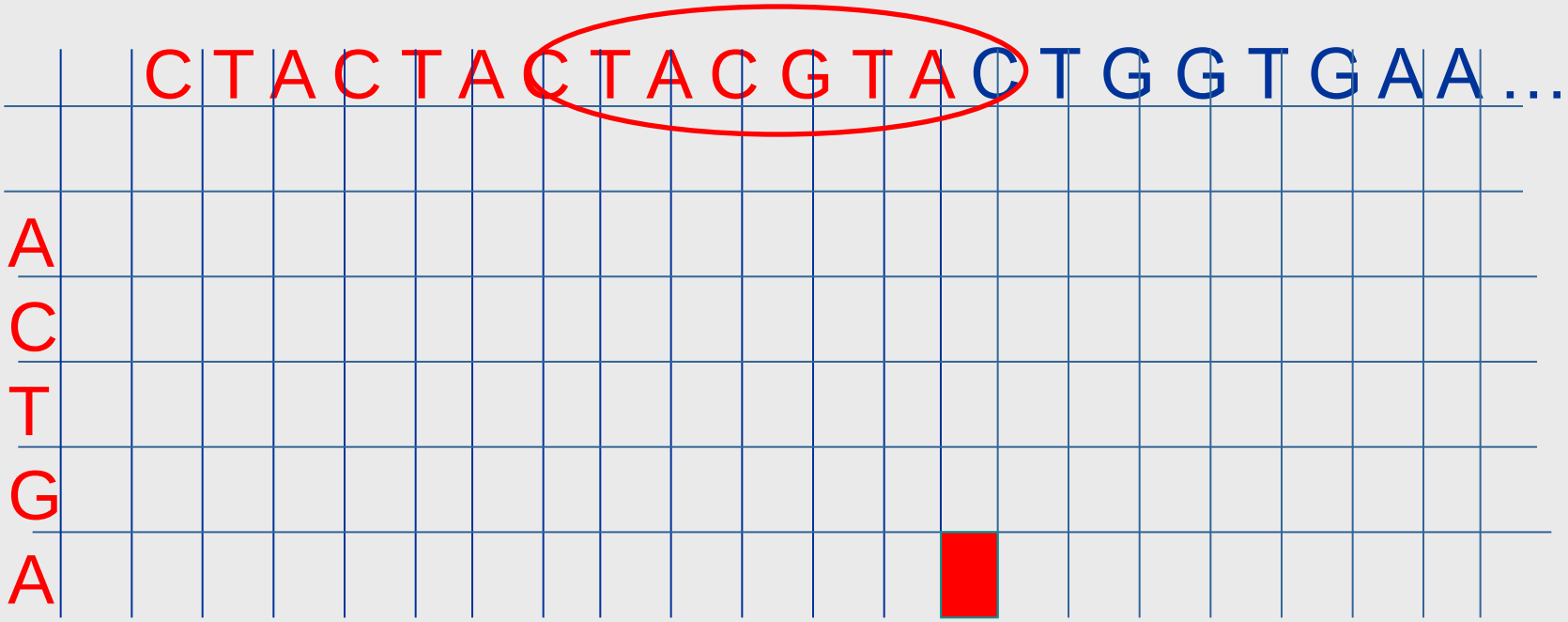
# K-approximate string searching




This cell gives the distance between (ACTGA, CT…GTA)…

…but we only are interested in the last characters

# K-approximate string searching

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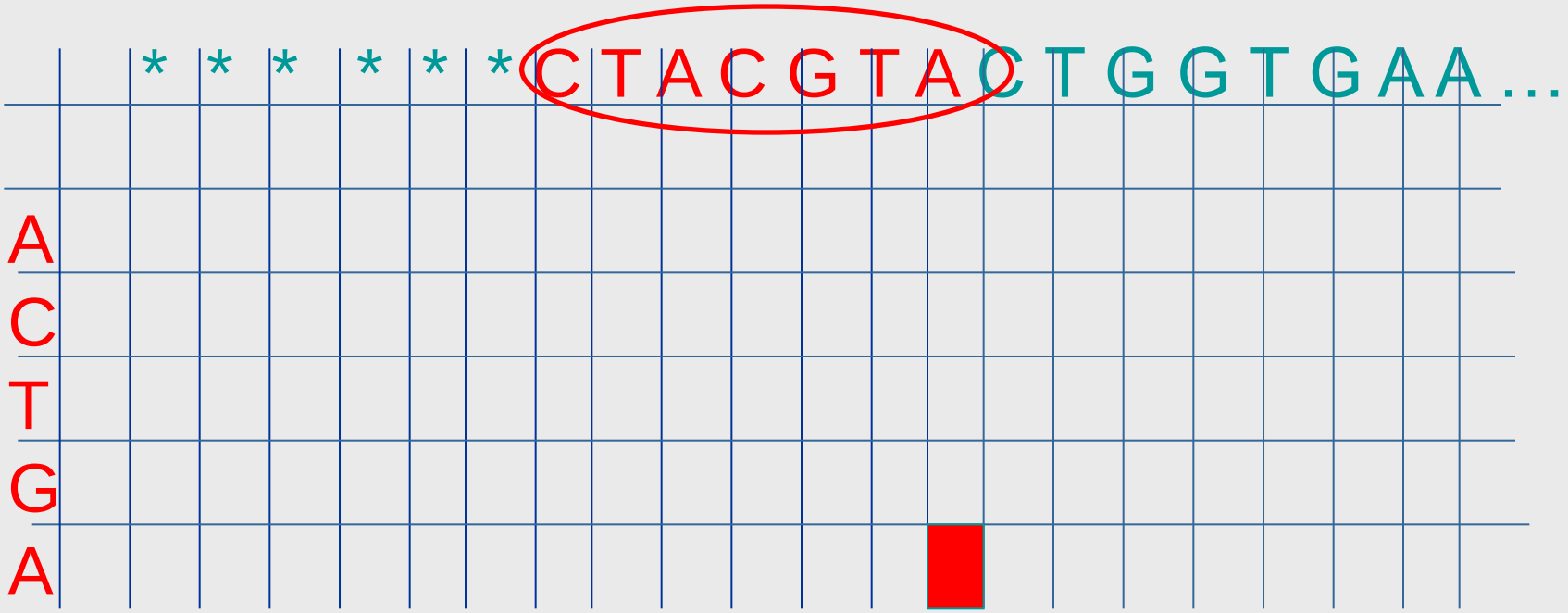


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…no matter where they appears in the text, then…

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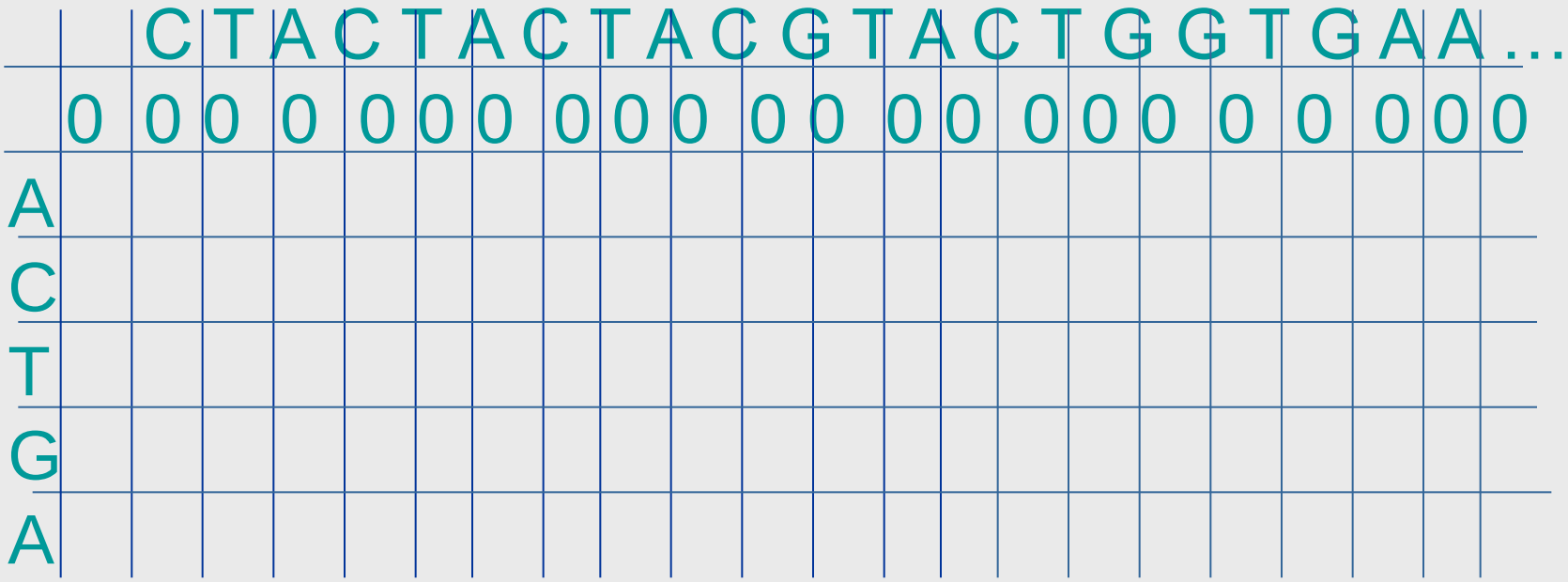


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and use the semi-global method.