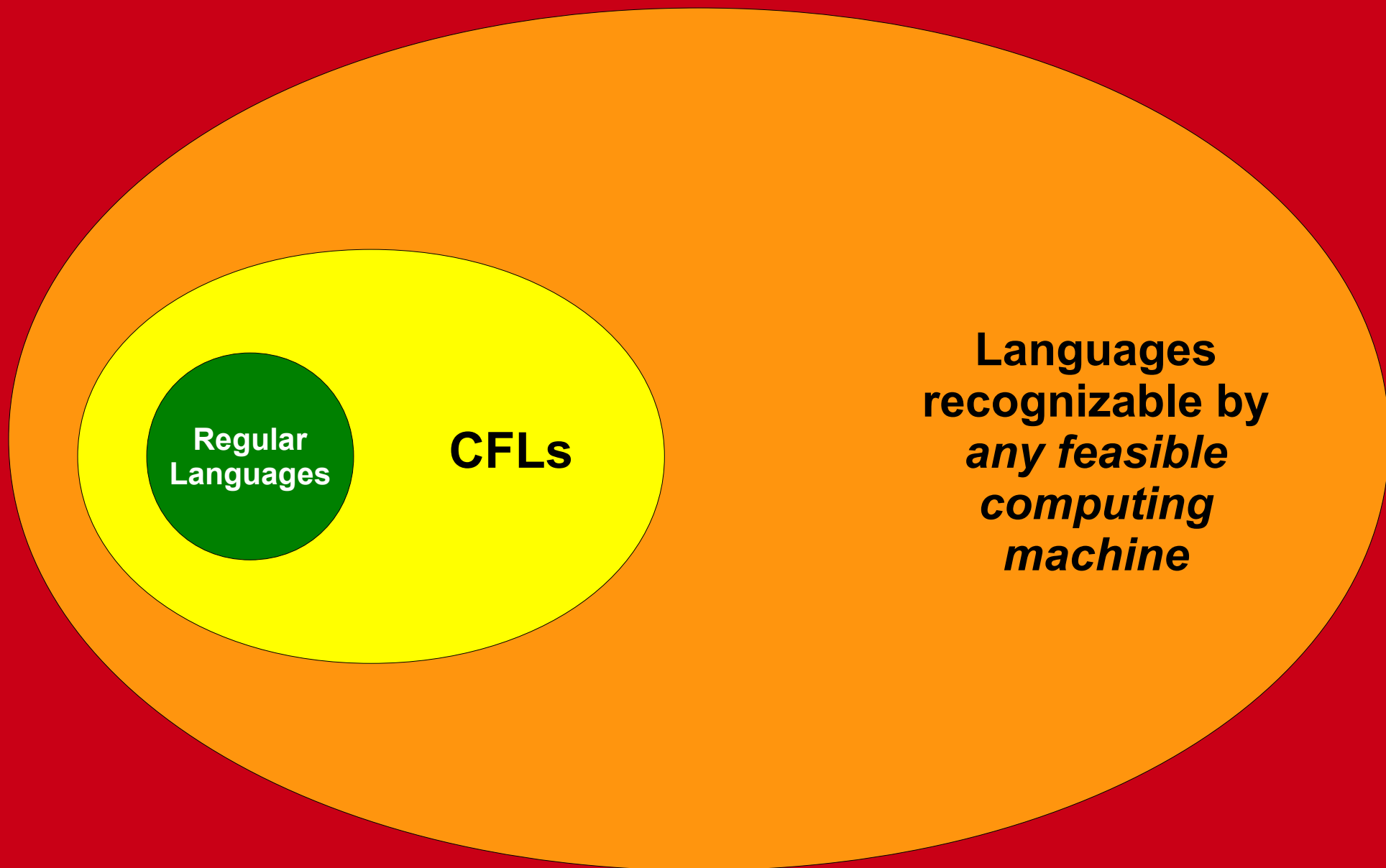


Turing Machines

Part One

What problems can we solve with a computer?



All Languages

That same drawing, to scale.

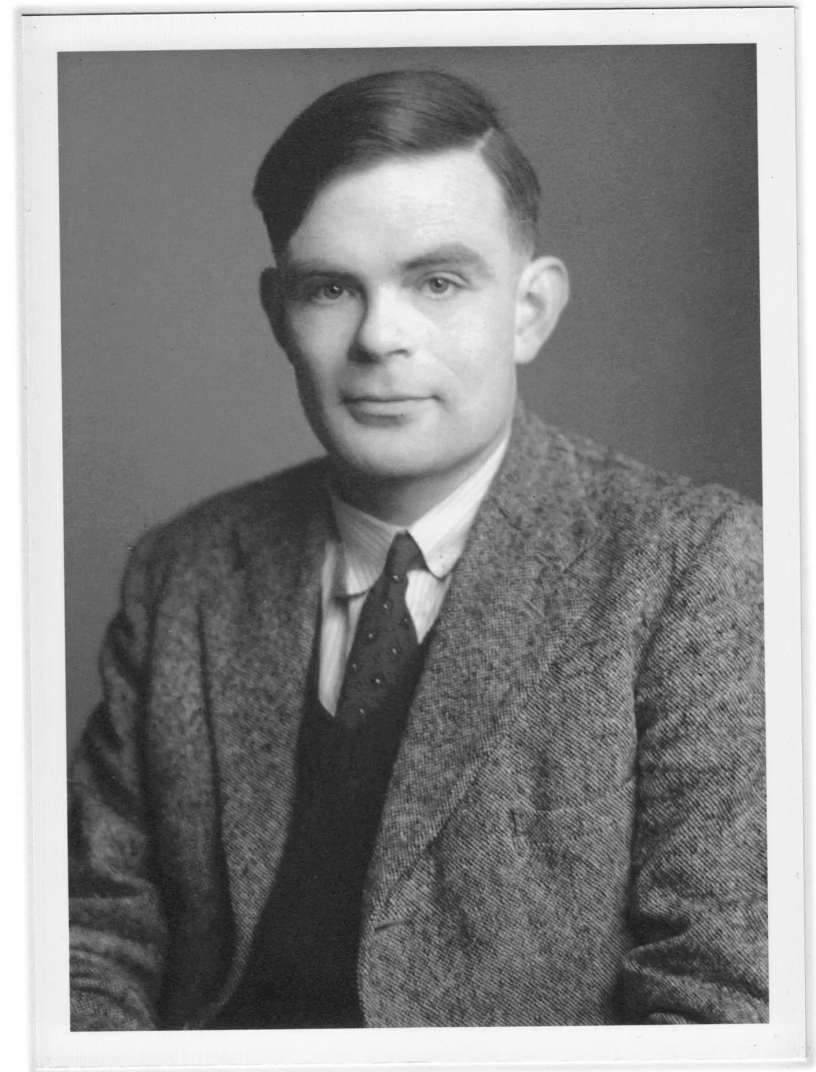
The Problem

- Finite automata accept precisely the regular languages.
- We may need unbounded memory to recognize context-free languages.
 - e.g. $\{ \mathbf{a}^n \mathbf{b}^n \mid n \in \mathbb{N} \}$ requires unbounded counting.
- How do we model a computing device that has unbounded memory?

A Brief History Lesson

Turing Machines

- In March 1936, Alan Turing (aged 23!) published a paper detailing the ***a-machine*** (for ***automatic machine***), an automaton for computing on real numbers.
- They're now more popularly referred to as ***Turing machines*** in his honor.
- He also later made contributions to computational biology, artificial intelligence, cryptography, etc. Seriously, Google this guy.



$$\begin{array}{r} 27182818284590 \\ + 31415926535897 \\ \hline \end{array}$$

$$\begin{array}{r} 27182818284590 \\ + 31415926535897 \\ \hline \end{array}$$

$$\begin{array}{r} 27182818284\overset{1}{5}90 \\ + 31415926535897 \\ \hline 27182818284\overset{1}{5}90 \\ 31415926535897 \\ \hline 58608744824997 \end{array}$$

$$\begin{array}{r}
 27182818284^1 590 \\
 + 31415926535^1 897 \\
 \hline
 487
 \end{array}$$

										1	1	1		
	2	7	1	8	2	8	1	8	2	8	4	5	9	0
+	3	1	4	1	5	9	2	6	5	3	5	8	9	7
											0	4	8	7

									1	1	1	1			
	2	7	1	8	2	8	1	8	2	8	4	5	9	0	
+	3	1	4	1	5	9	2	6	5	3	5	8	9	7	
										2	0	4	8	7	

$$\begin{array}{r} 27182818 \mathbf{2} 84590 \\ + 31415926 \mathbf{5} 35897 \\ \hline 27182818 \mathbf{8} 20487 \end{array}$$

							1		1	1	1	1			
	2	7	1	8	2	8	1	8	2	8	4	5	9	0	
+	3	1	4	1	5	9	2	6	5	3	5	8	9	7	
								4	8	2	0	4	8	7	

							1		1	1	1	1		
	2	7	1	8	2	8	1	8	2	8	4	5	9	0
+	3	1	4	1	5	9	2	6	5	3	5	8	9	7
							4	4	8	2	0	4	8	7

$$\begin{array}{r} \textbf{8} \\ + \textbf{9} \\ \hline \textbf{7} \end{array}$$

Carry values (1) are shown above the digits 2, 1, 2, 8, 4, and 5 in the second row.

					1		1		1	1	1	1		
	2	7	1	8	2	8	1	8	2	8	4	5	9	0
+	3	1	4	1	5	9	2	6	5	3	5	8	9	7
					8	7	4	4	8	2	0	4	8	7

					1		1		1	1	1	1		
	2	7	1	8	2	8	1	8	2	8	4	5	9	0
+	3	1	4	1	5	9	2	6	5	3	5	8	9	7
				9	8	7	4	4	8	2	0	4	8	7

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	2	7	1	8	2	8	1	8	2	8	4	5	9 0
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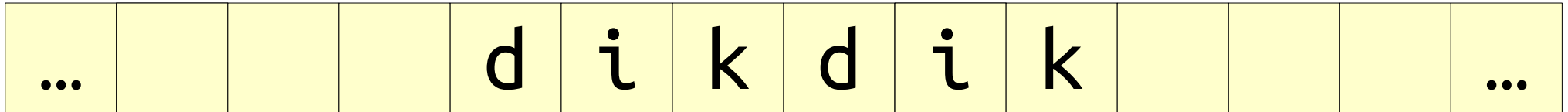
					1		1		1	1	1	1		
	2	7	1	8	2	8	1	8	2	8	4	5	9	0
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Key Idea: Even if you need huge amounts of scratch space to perform a calculation, at each point in the calculation you only need access to a small amount of that scratch space.

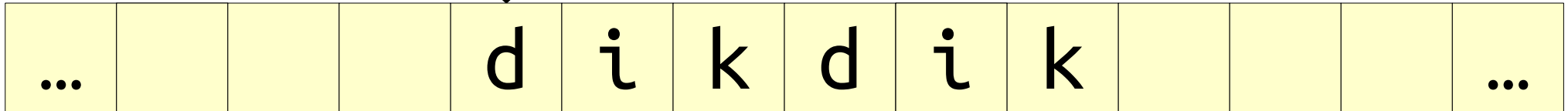
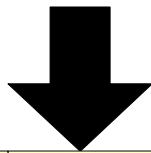
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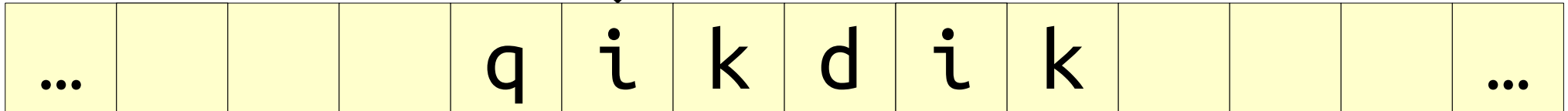
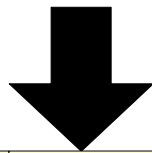
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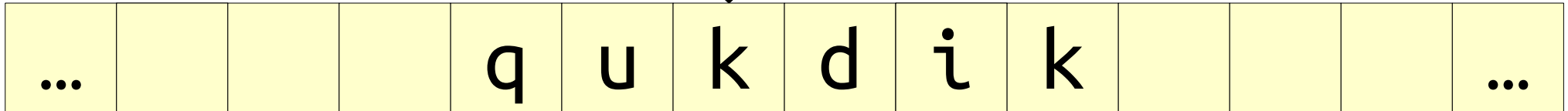
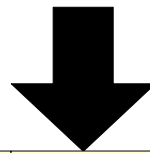
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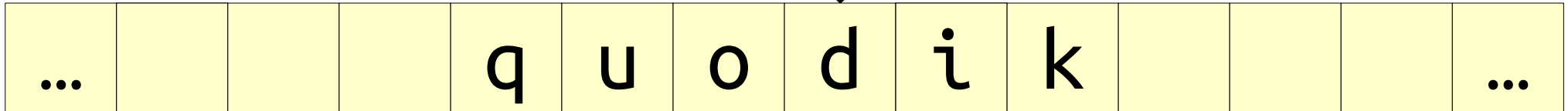
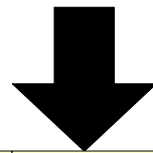
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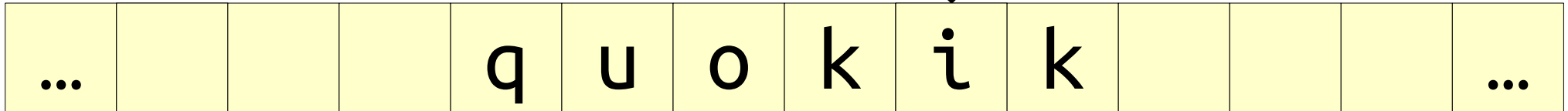
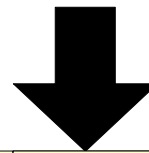
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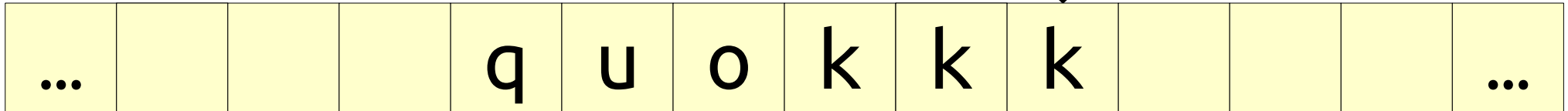
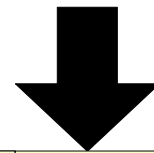
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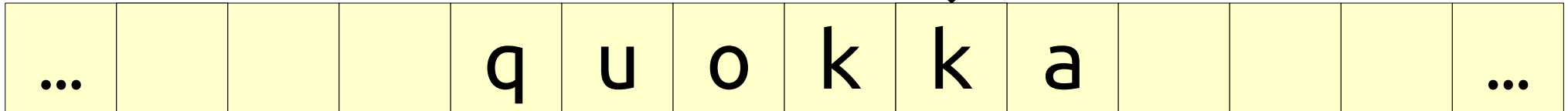
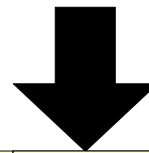
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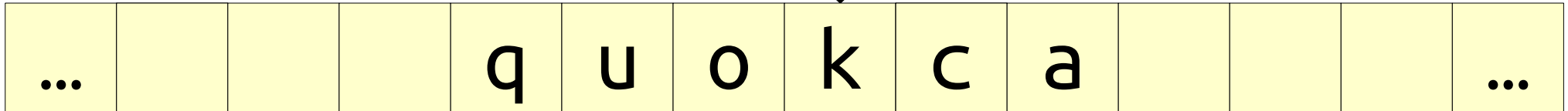
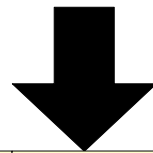
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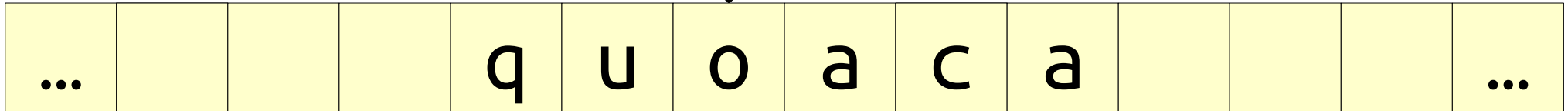
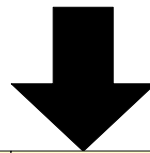
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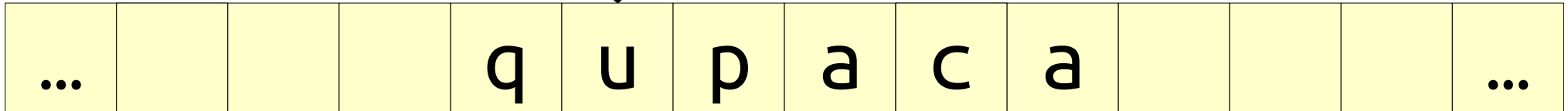
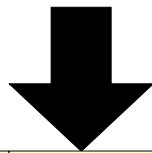
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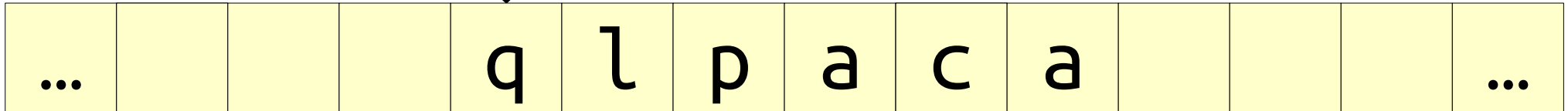
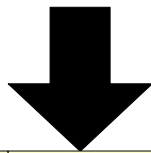
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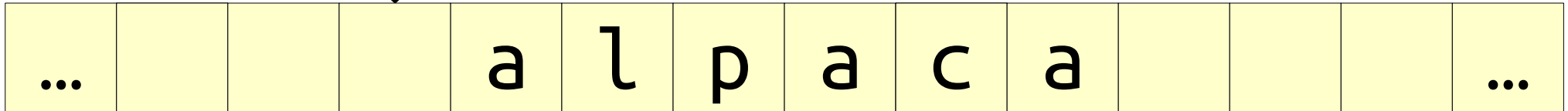
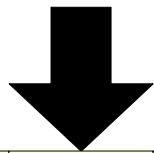
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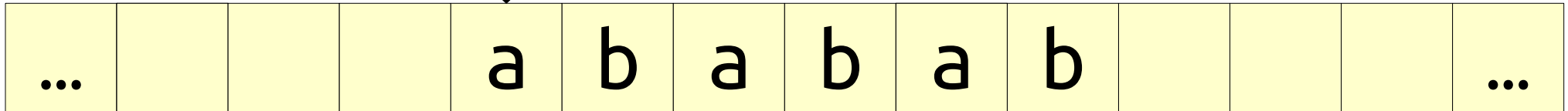
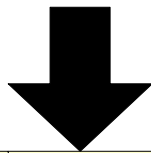
- Over the years, there have been many simplifications and edits to Turing's original automata.
 - In practice, electronic computers are written in terms of individual instructions rather than states and transitions.
 - Turing's original paper deals with computing individual real numbers; we typically want to compute functions of inputs.
- What we're going to present as "Turing machines" in this class differ significantly from Turing's original description, while retaining the core essential ideas.
 - (Our model is closer to Emil Post's *Formulation 1* and Hao Wang's *Basic Machine B*, for those of you who are curious.)

Turing Machines

- A TM is a series of instructions that control a tape head as it moves across an infinite tape.
- The tape begins with the input string written somewhere, surrounded by infinitely many blank cells.
 - Rule: The input string cannot contain blank cells.
- The tape head begins above the first character of the input. (If the input is ϵ , the tape head points somewhere on a blank tape.)

Start:

```
If Blank Return True
If 'b' Return False
Write 'x'
Move Right
If Not 'b' Return False
Write 'x'
Move Right
Goto Start
```

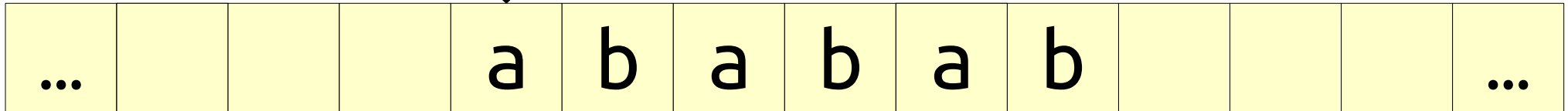
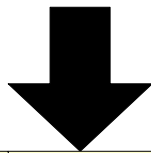


Turing Machines

- We begin at the Start label.
- Labels indicate different sections of code. The name Start is special and means “begin here.”
- Labels have no effect when executed. We just move to the next line.

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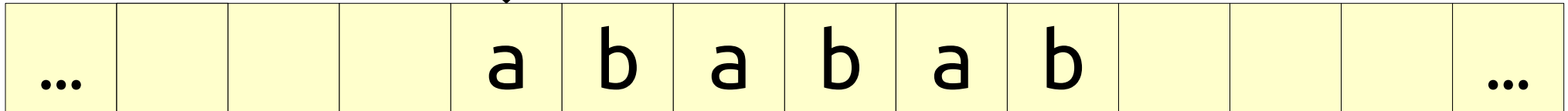
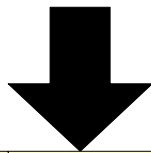


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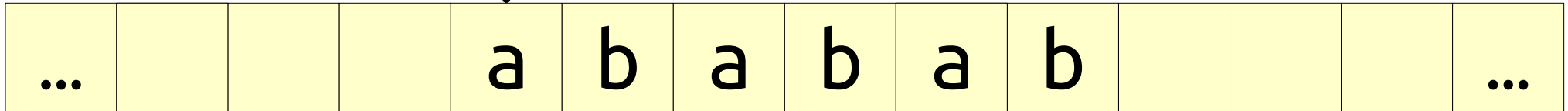
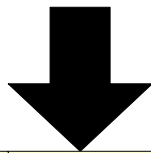
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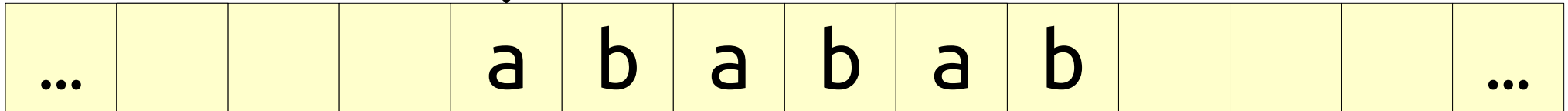
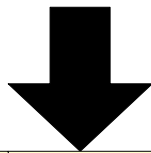
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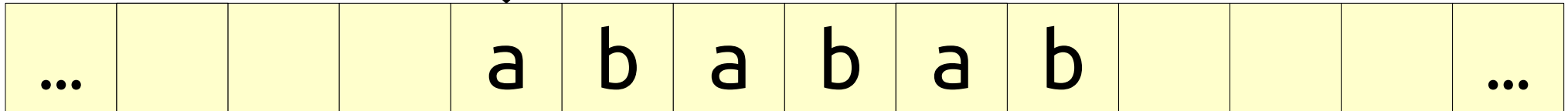
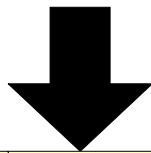
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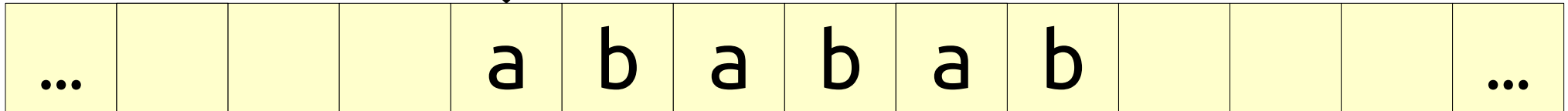
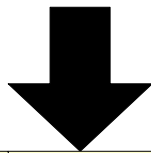
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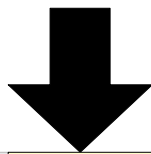
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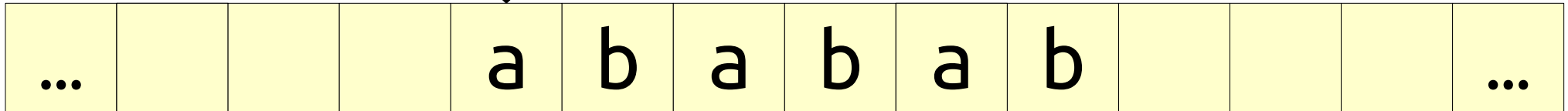
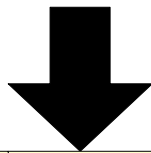
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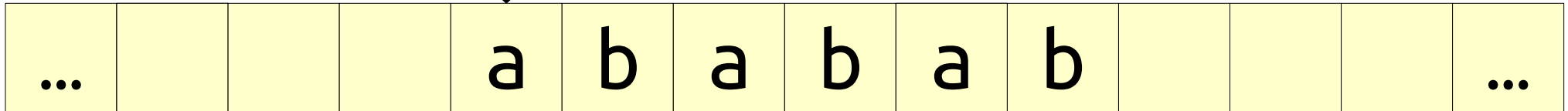
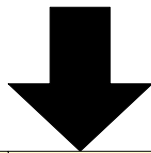
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checks if the character under the tape head is *symbol*.
- If so, it executes *command*.
- If not, nothing happens.

Start:

If Blank Return True

If 'b' Return False

Write 'x'

Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- A statement of the form
If *symbol* *command*
checks if the character under the tape head is *symbol*.
- If so, it executes *command*.
- If not, nothing happens.

Start:

If Blank Return True

If 'b' Return False

Write 'x'

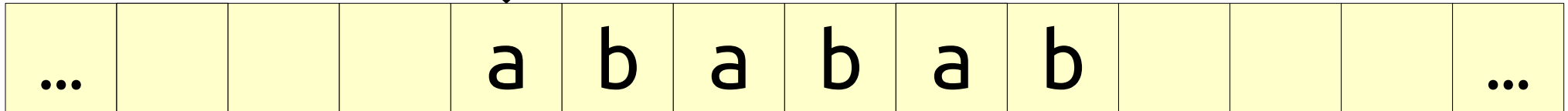
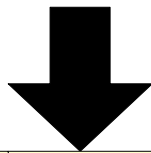
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- A statement of the form
If *symbol* *command*
checks if the character under the tape head is *symbol*.
- If so, it executes *command*.
- If not, nothing happens.

Start:

If Blank Return True

If 'b' Return False

Write 'x'

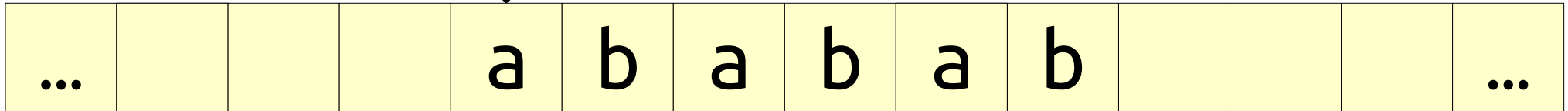
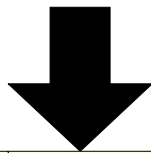
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- The statement
Write *symbol*
writes *symbol* to the
cell under the tape
head.
- The *symbol* can either
be Blank or a character
in quotes.

Start:

If Blank Return True

If 'b' Return False

Write 'x'

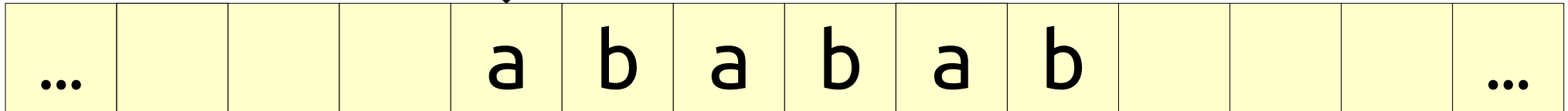
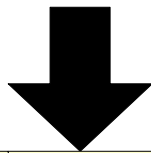
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- The statement
Write *symbol*
writes *symbol* to the
cell under the tape
head.
- The *symbol* can either
be Blank or a character
in quotes.

Start:

If Blank Return True

If 'b' Return False

Write 'x'

Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- The statement
Write *symbol*
writes *symbol* to the
cell under the tape
head.
- The *symbol* can either
be Blank or a character
in quotes.

Start:

If Blank Return True

If 'b' Return False

Write 'x'

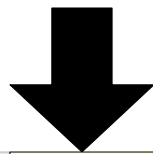
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- The statement
Write *symbol*
writes *symbol* to the
cell under the tape
head.
- The *symbol* can either
be Blank or a character
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If Blank Return True

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Write 'x'

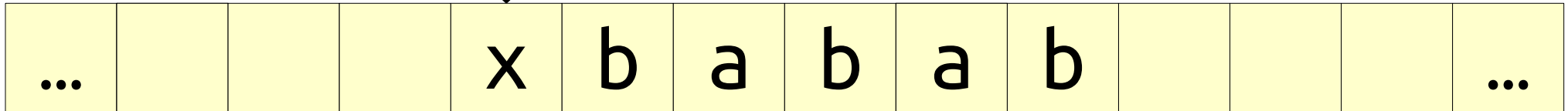
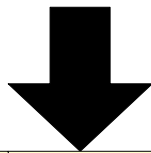
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

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Write *symbol*
writes *symbol* to the
cell under the tape
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Start:

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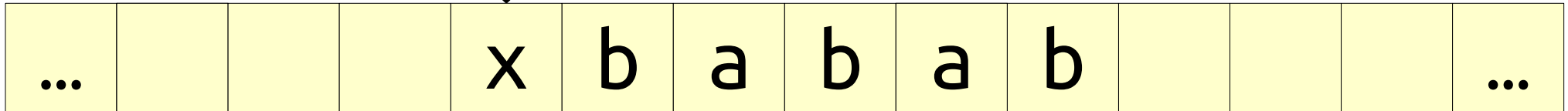
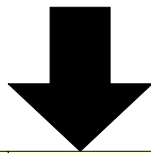
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- The command
Move *direction*
moves the tape head
one step in the
indicated direction
(either Left or Right).

Start:

If Blank Return True

If 'b' Return False

Write 'x'

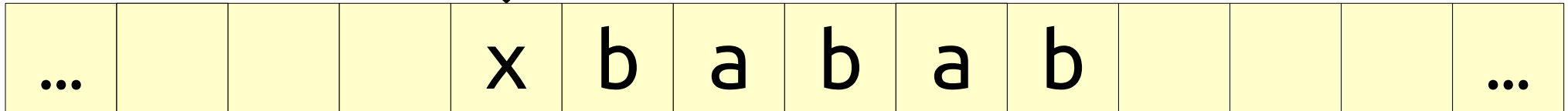
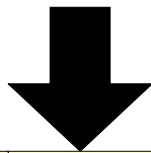
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- The command
Move *direction*
moves the tape head
one step in the
indicated direction
(either Left or Right).

Start:

If Blank Return True

If 'b' Return False

Write 'x'

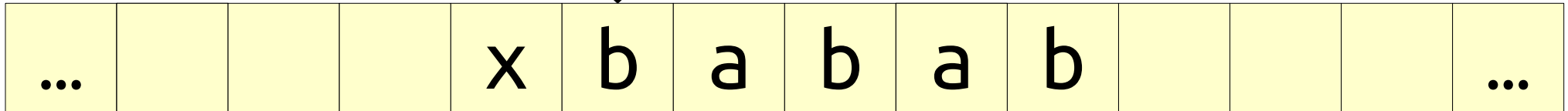
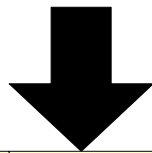
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- The command
Move *direction*
moves the tape head
one step in the
indicated direction
(either Left or Right).

Start:

If Blank Return True

If 'b' Return False

Write 'x'

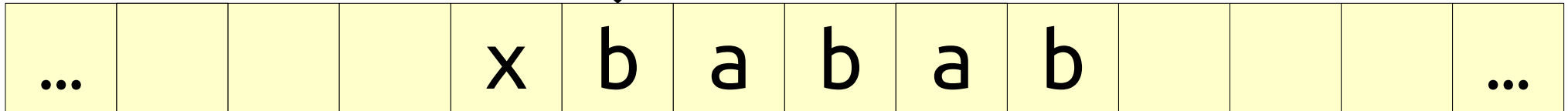
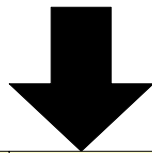
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- A statement of the form
If Not *symbol command*
sees if the cell under the
tape head holds *symbol*.
- If so, nothing happens.
- If not, it executes
command.

Start:

If Blank Return True

If 'b' Return False

Write 'x'

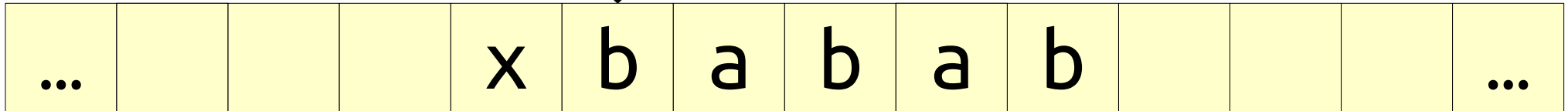
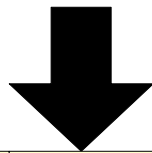
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Goto Start



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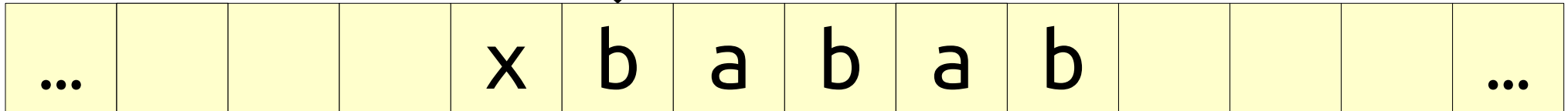
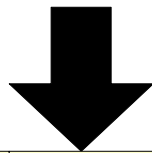
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



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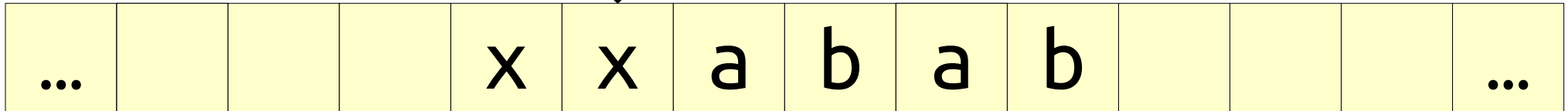
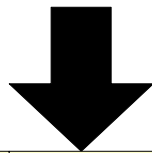
Move Right

If Not 'b' Return False

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Move Right

Goto Start



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command.

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Write 'x'

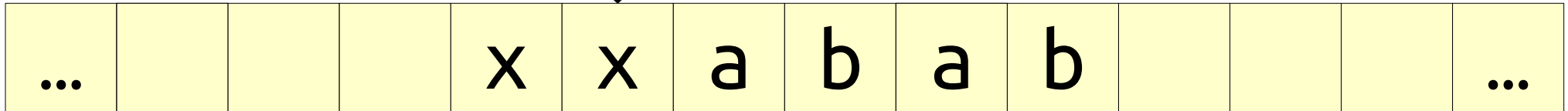
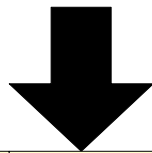
Move Right

If Not 'b' Return False

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Move Right

Goto Start



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command.

Start:

If Blank Return True

If 'b' Return False

Write 'x'

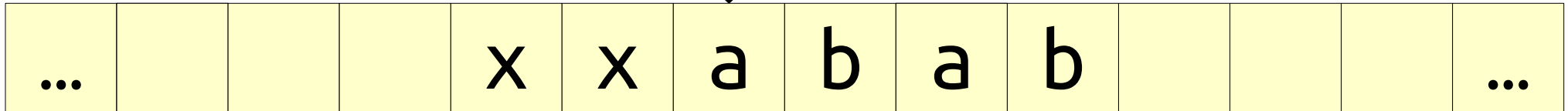
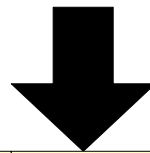
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- A statement of the form
If Not *symbol command*
sees if the cell under the
tape head holds *symbol*.
- If so, nothing happens.
- If not, it executes
command.

Start:

If Blank Return True

If 'b' Return False

Write 'x'

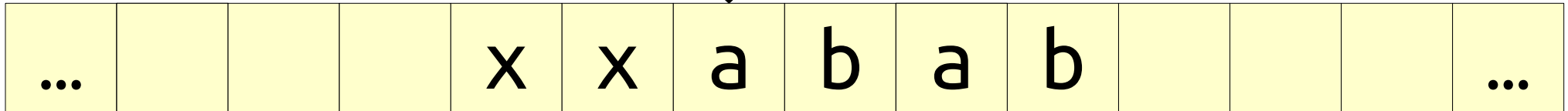
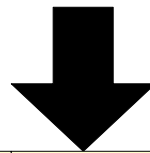
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start

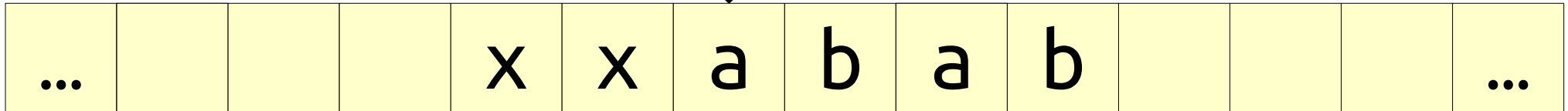
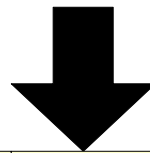


Turing Machines

- The command
Goto *label*
jumps to the indicated label.
- This program just has a Start label, but most interesting programs have other labels beyond this.

Start:

```
If Blank Return True  
If 'b' Return False  
Write 'x'  
Move Right  
If Not 'b' Return False  
Write 'x'  
Move Right  
Goto Start
```

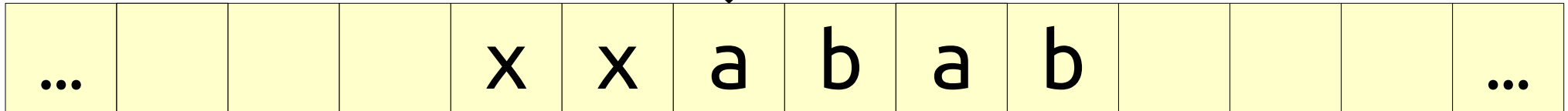
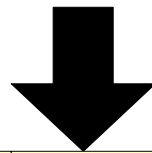


Turing Machines

- The command
Goto *label*
jumps to the indicated label.
- This program just has a Start label, but most interesting programs have other labels beyond this.

Start:

```
If Blank Return True  
If 'b' Return False  
Write 'x'  
Move Right  
If Not 'b' Return False  
Write 'x'  
Move Right  
Goto Start
```

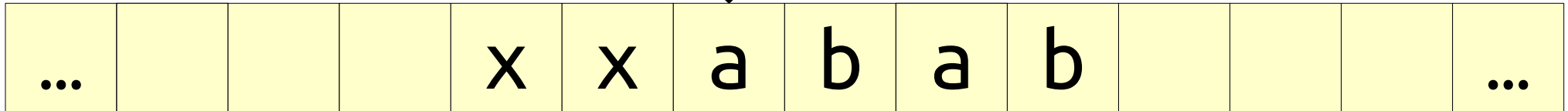
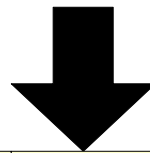


Turing Machines

- A TM stops when executing the **Return *result*** command.
- Here, *result* can be either True or False.
- (If we “fall off” the bottom of the program, the TM acts as though it executes the Return False command.)

Start:

```
If Blank Return True
If 'b' Return False
Write 'x'
Move Right
If Not 'b' Return False
Write 'x'
Move Right
Goto Start
```



Turing Machines

- A TM stops when executing the **Return *result*** command.
- Here, *result* can be either True or False.
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Start:

If Blank Return True

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Write 'x'

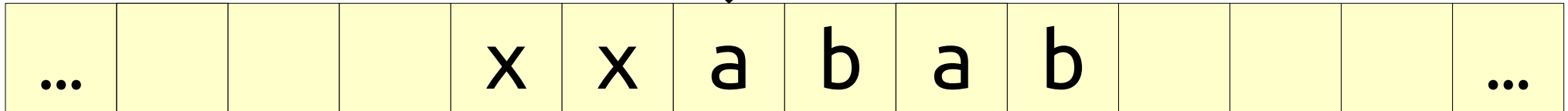
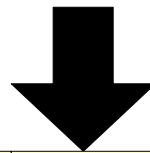
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

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Start:

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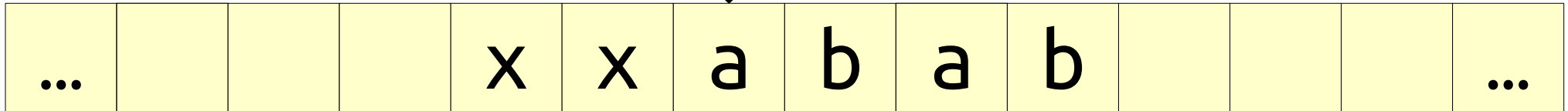
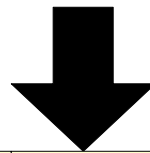
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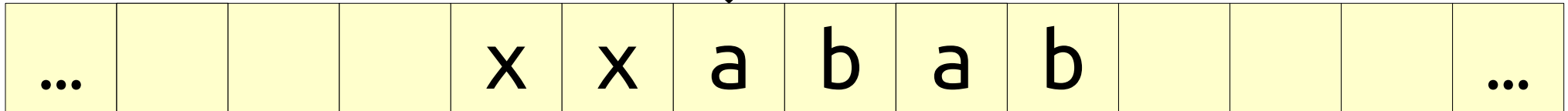
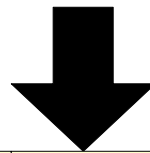
Move Right

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If 'b' Return False

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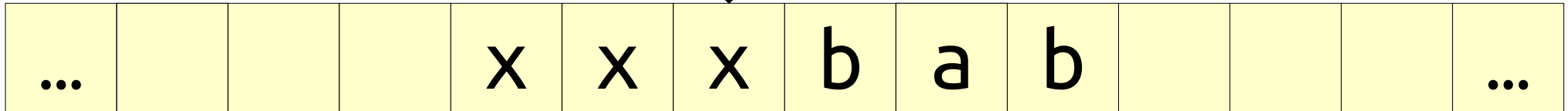
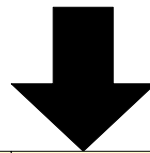
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If Not 'b' Return False

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Goto Start



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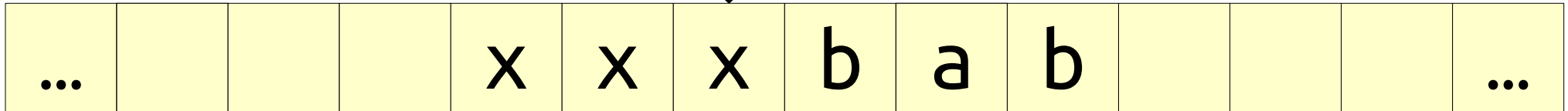
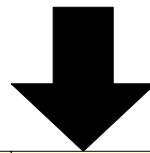
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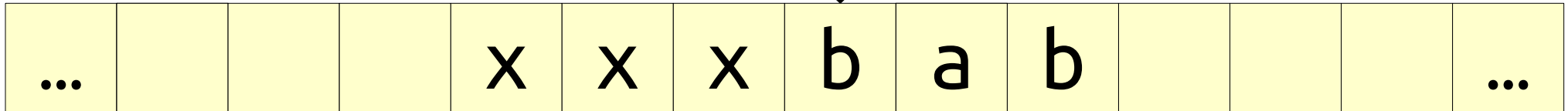
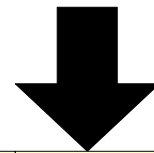
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



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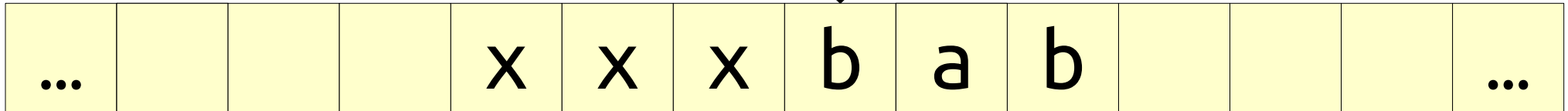
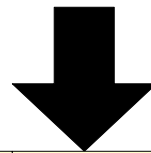
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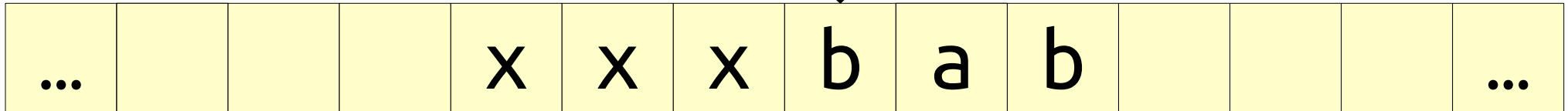
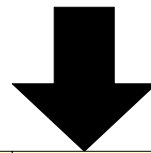
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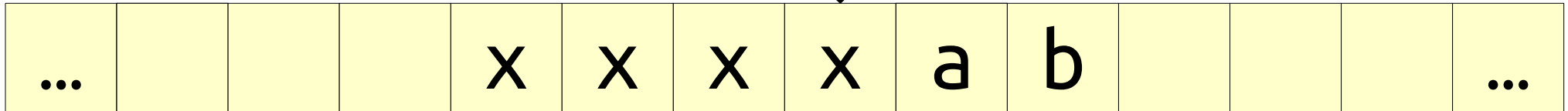
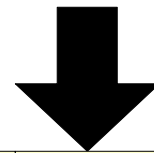
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Goto Start



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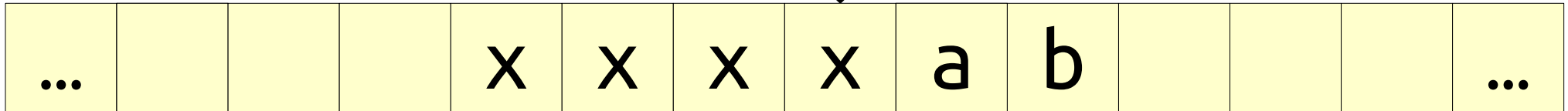
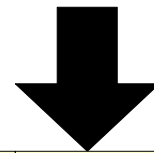
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Write 'x'

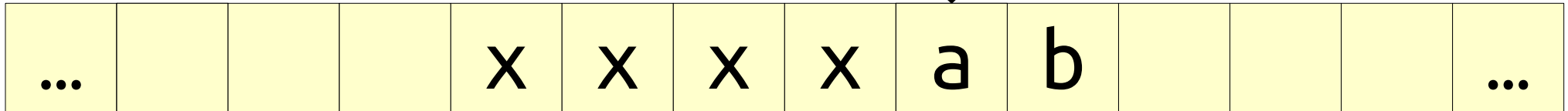
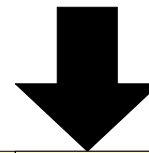
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

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Start:

If Blank Return True

If 'b' Return False

Write 'x'

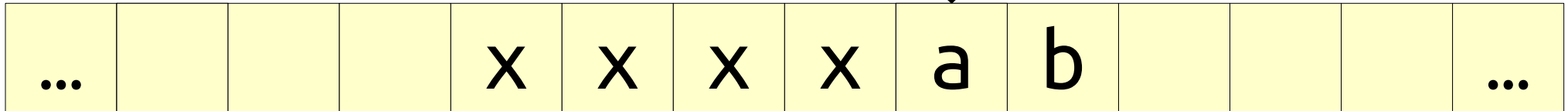
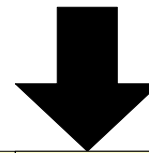
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start

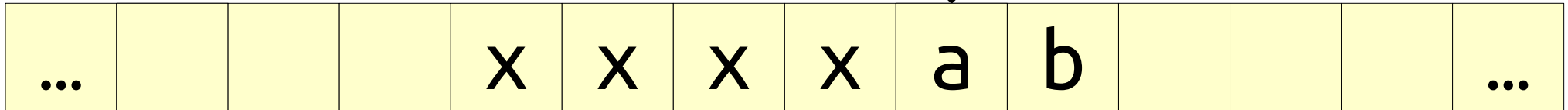
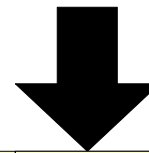


Turing Machines

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Start:

```
If Blank Return True
If 'b' Return False
Write 'x'
Move Right
If Not 'b' Return False
Write 'x'
Move Right
Goto Start
```



Turing Machines

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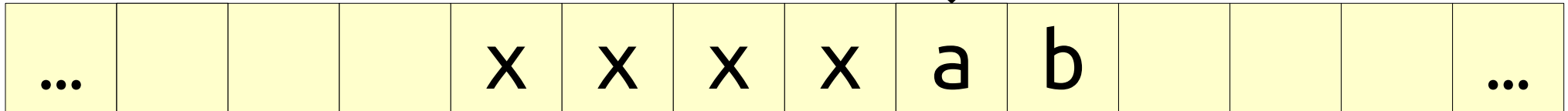
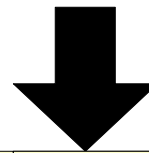
Move Right

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Goto Start



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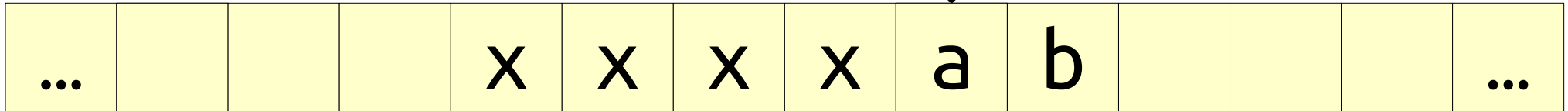
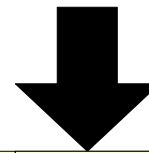
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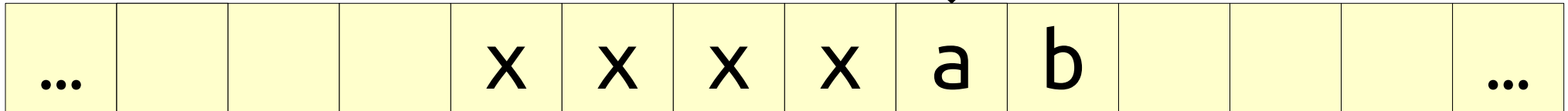
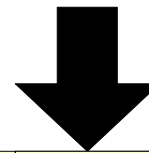
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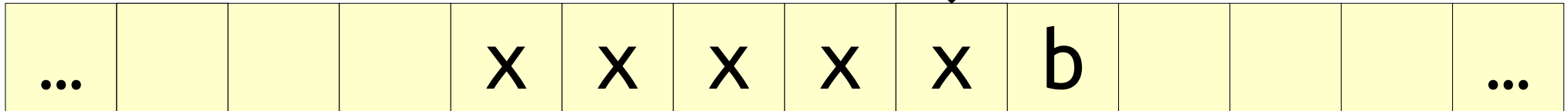
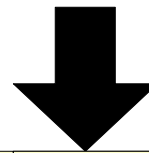
Move Right

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Move Right

Goto Start



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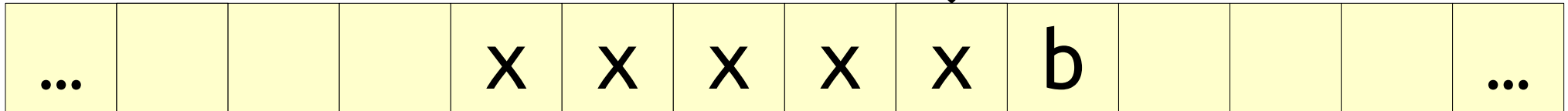
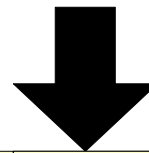
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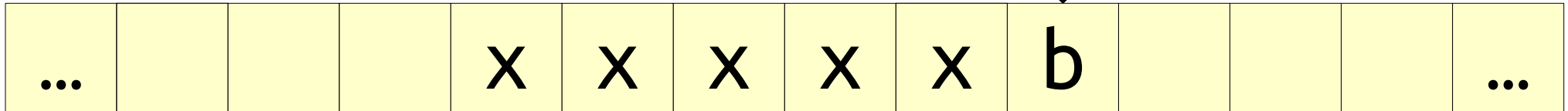
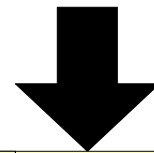
Move Right

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Goto Start



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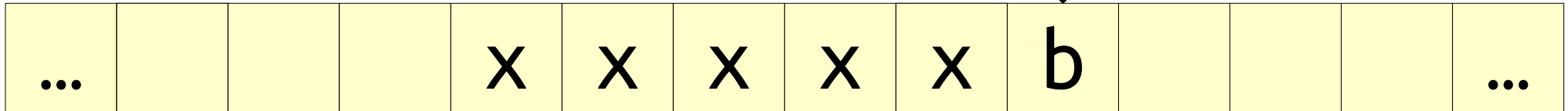
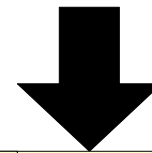
Move Right

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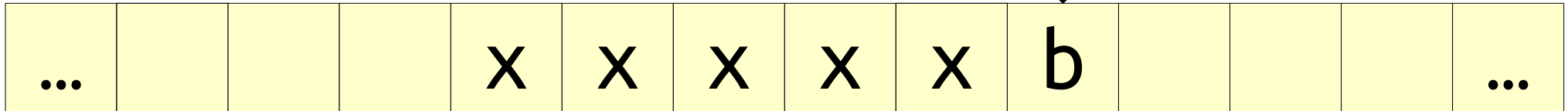
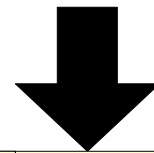
Move Right

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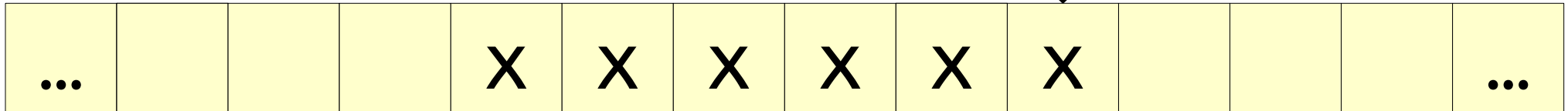
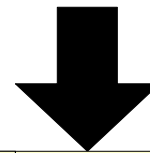
Move Right

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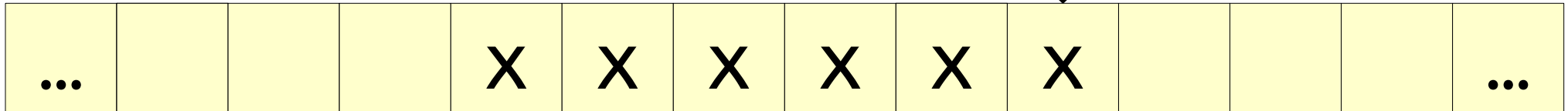
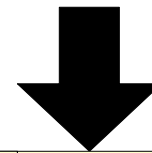
Move Right

If Not 'b' Return False

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Move Right

Goto Start



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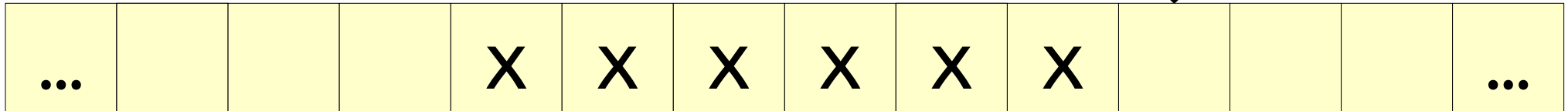
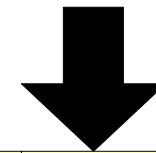
Move Right

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Move Right

Goto Start



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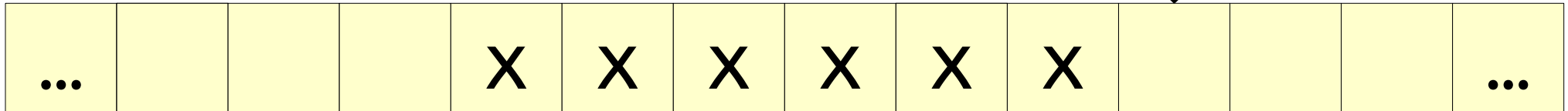
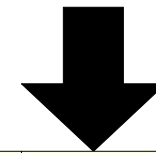
Move Right

If Not 'b' Return False

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Move Right

Goto Start

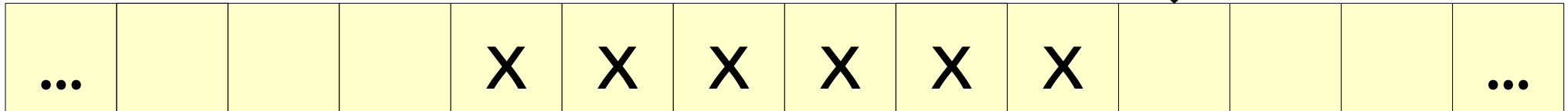
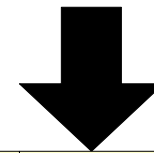


Turing Machines

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Start:

```
If Blank Return True
If 'b' Return False
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Move Right
If Not 'b' Return False
Write 'x'
Move Right
Goto Start
```



Turing Machines

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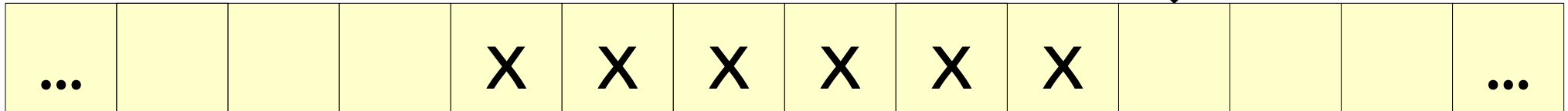
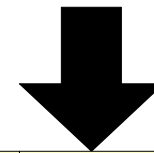
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Start:

If Blank Return True □

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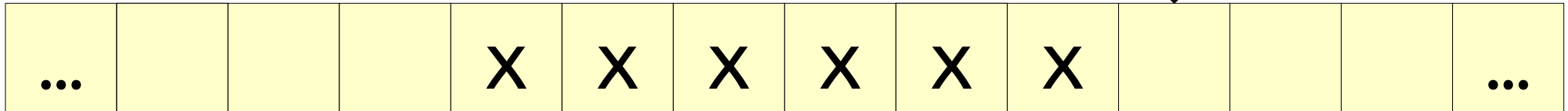
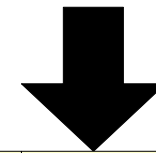
Move Right

If Not 'b' Return False

Write 'x'

Move Right

Goto Start



Turing Machines

- This TM initially started up with the string ababab on its tape, so this means that TM returns true on the input ababab, not xxxxxx.
- An intuition for this: we gave this program an input. It therefore returned true with respect to that input, not whatever internal data it generated in making its decision.

Start:

If Blank Return True □

If 'b' Return False

Write 'x'

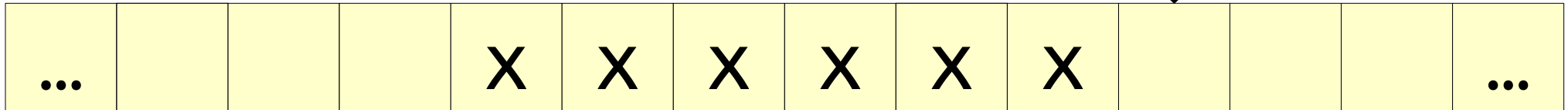
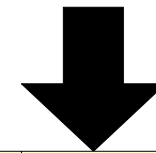
Move Right

If Not 'b' Return False

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Move Right

Goto Start

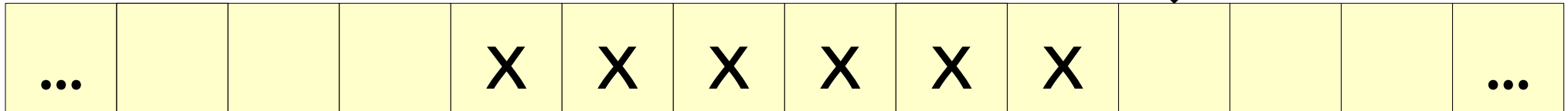
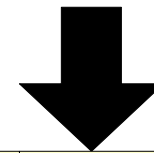


Turing Machines

- To summarize, we only have six commands:
 - Move *direction*
 - Write *symbol*
 - Goto *label*
 - Return *result*
 - If *symbol command*
 - If Not *symbol command*
- Despite their simplicity, TMs are *surprisingly* powerful. The rest of this lecture explores why.

Start:

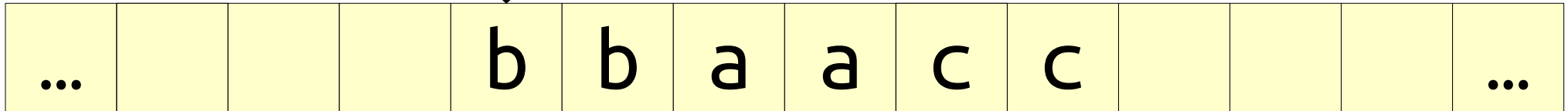
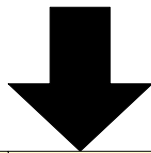
```
If Blank Return True
If 'b' Return False
Write 'x'
Move Right
If Not 'b' Return False
Write 'x'
Move Right
Goto Start
```



Your Turn!

- Does this TM accept or reject bbaacc?
- More generally, what does this TM do?

Go to
PollEv.com/cs103spr25



Start:

If 'a' Goto Mirth

If Blank Return False

Move Right

Goto Start

Mirth:

If 'b' Return True

If Blank Return False

Move Right

Goto Mirth

Programming Turing Machines

Our First Challenge

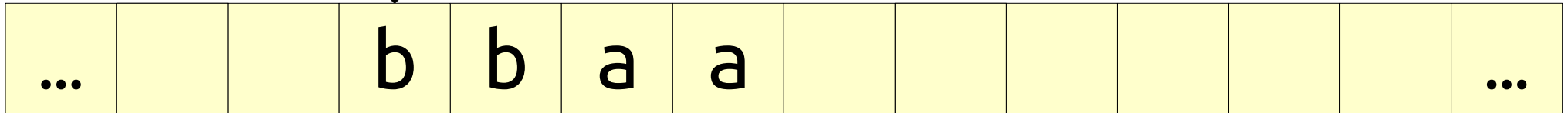
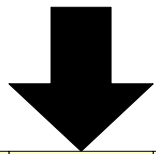
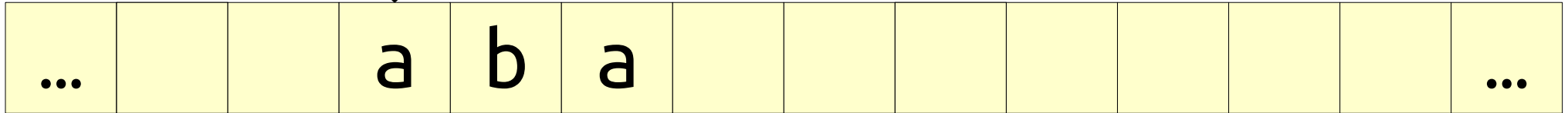
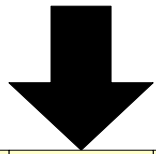
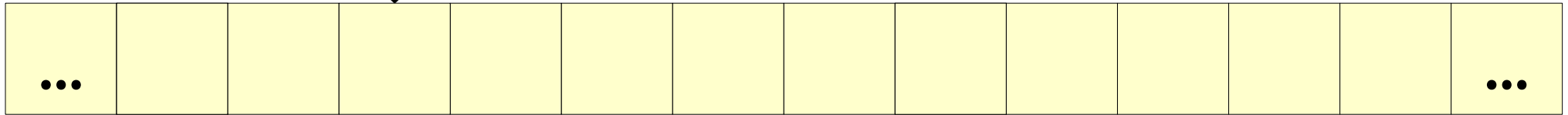
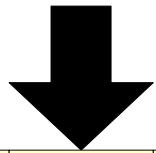
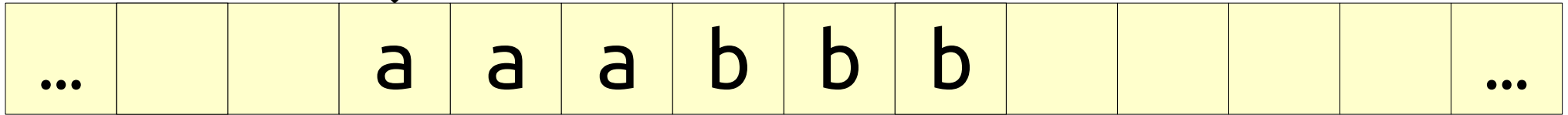
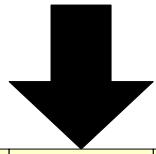
- The language

$$\{ \mathbf{a}^n \mathbf{b}^n \mid n \in \mathbb{N} \}$$

is a canonical example of a nonregular language. It's not possible to check if a string is in this language given only finite memory.

- Turing machines, however, are powerful enough to do this. Let's see how.

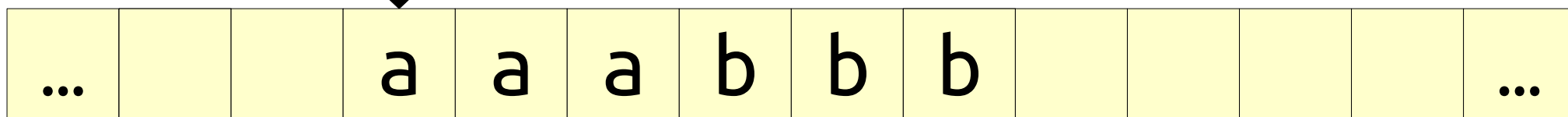
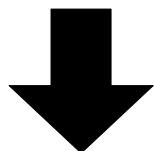
$$L = \{ \mathbf{a}^n \mathbf{b}^n \mid n \in \mathbb{N} \}$$



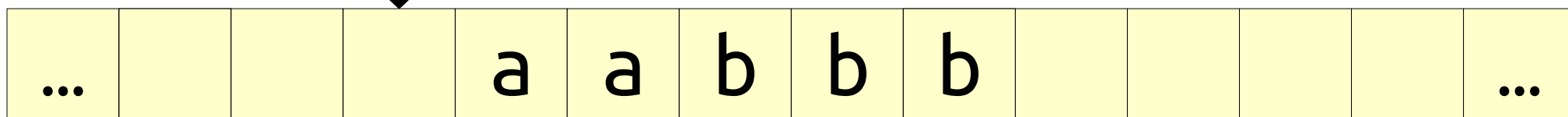
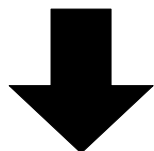
A Recursive Approach

- We can process our string using a recursive approach:
 - The string ε is in L .
 - The string **a** w **b** is in L if and only if w is in L .
 - Any string starting with **b** is not in L .
 - Any string ending with **a** is not in L .
- All that's left to do now is write a TM that implements this.

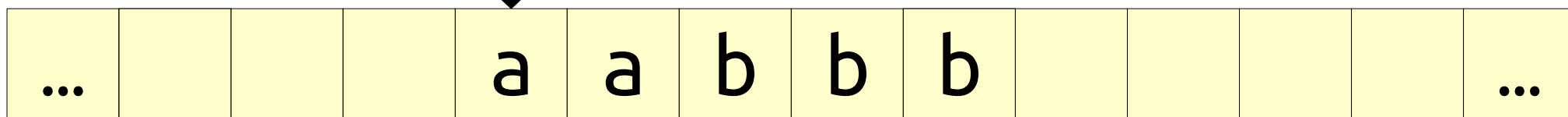
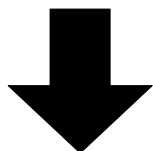
A Sketch of our TM



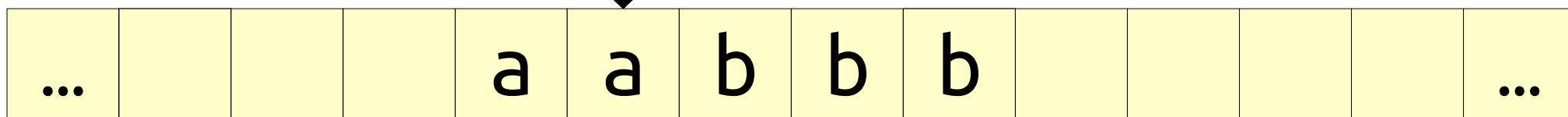
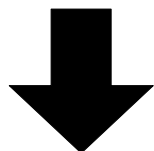
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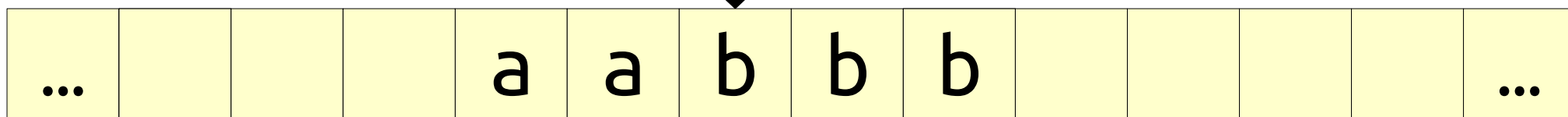
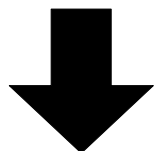
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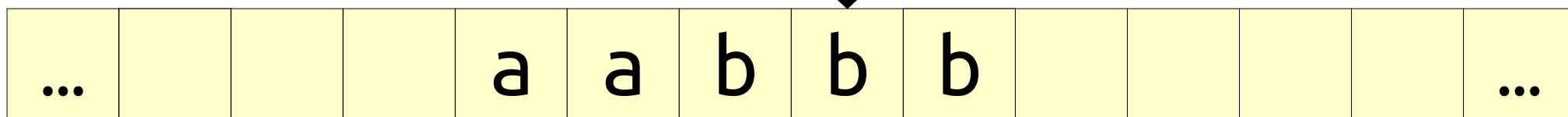
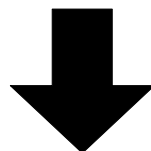
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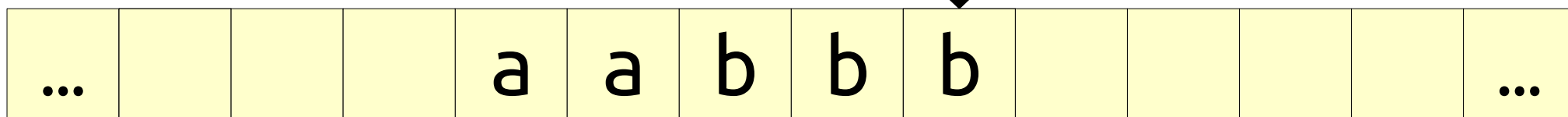
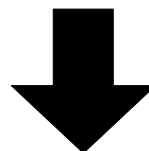
A Sketch of our TM



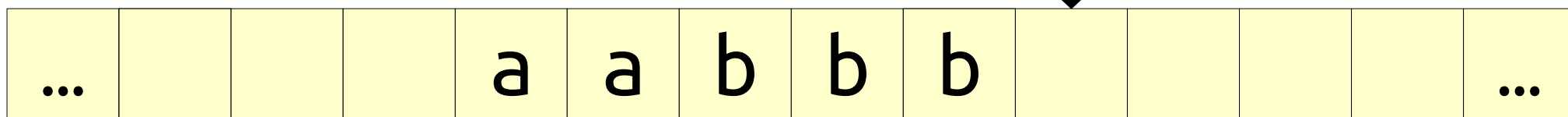
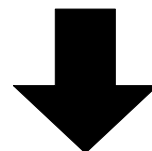
A Sketch of our TM



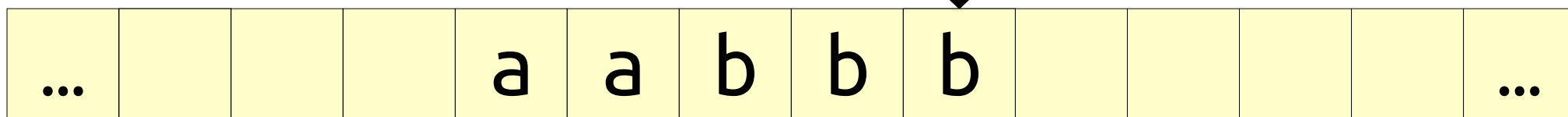
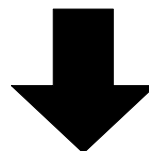
A Sketch of our TM



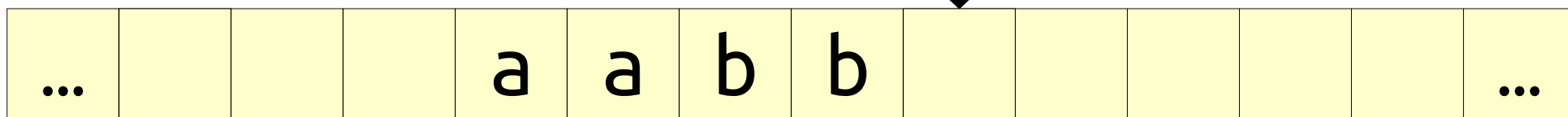
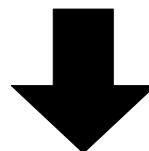
A Sketch of our TM



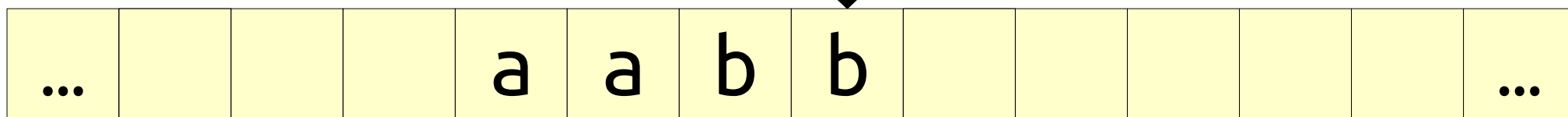
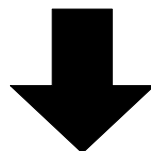
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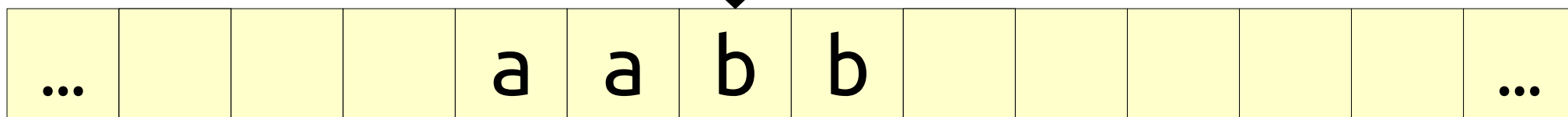
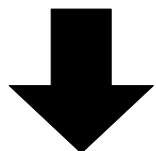
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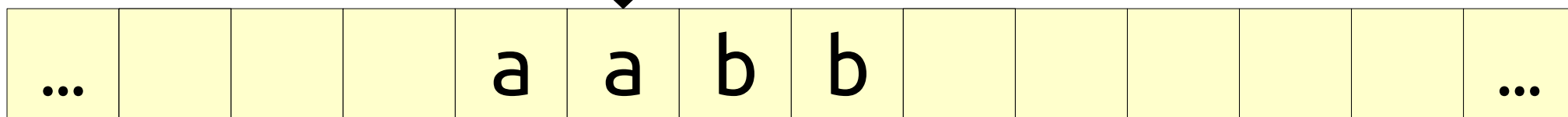
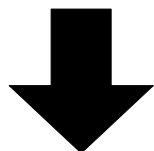
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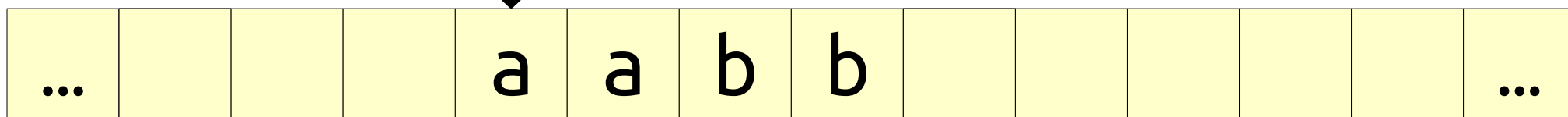
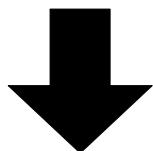
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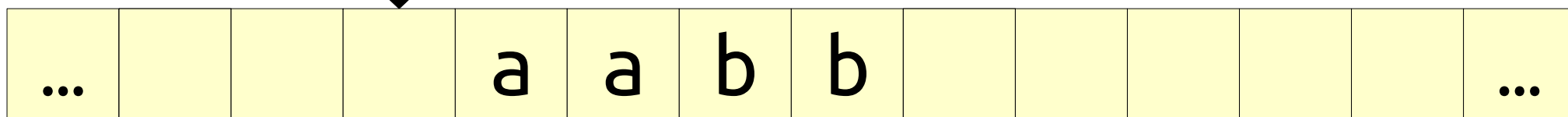
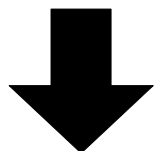
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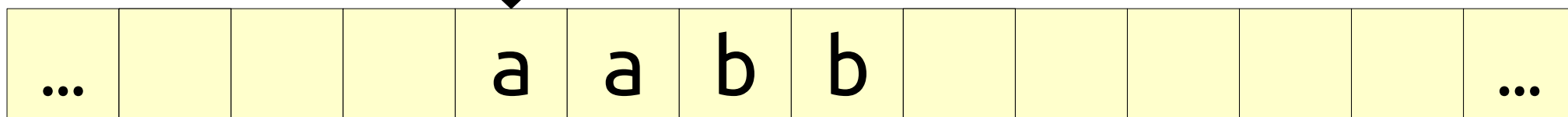
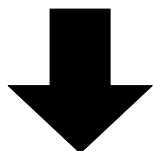
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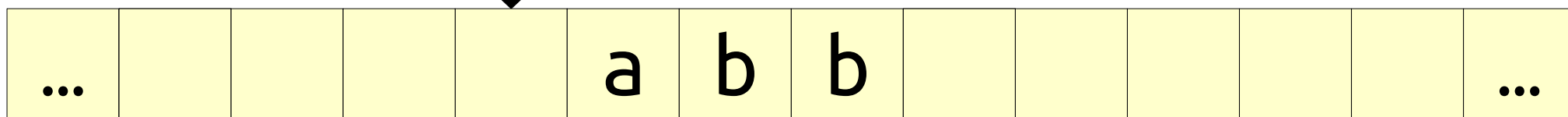
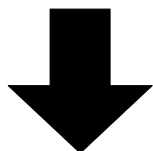
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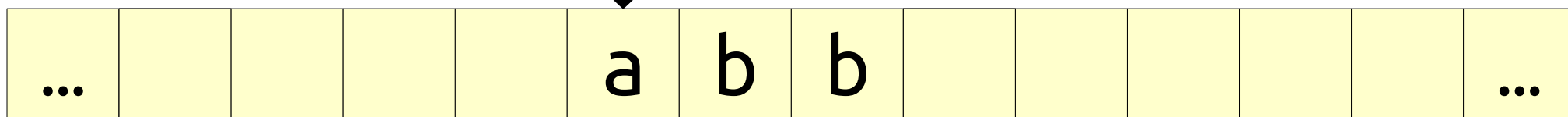
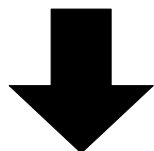
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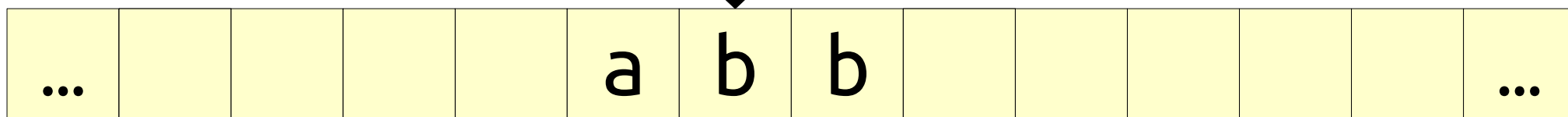
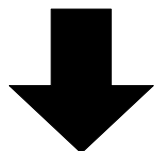
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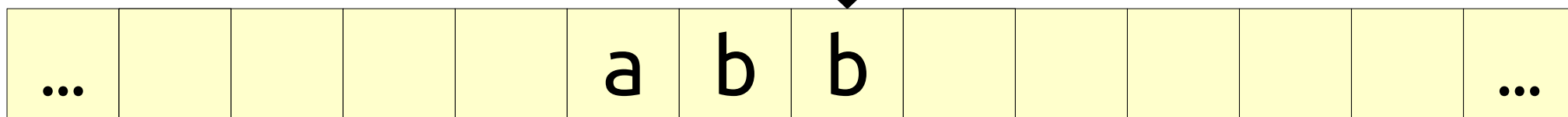
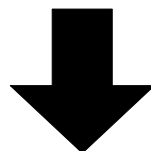
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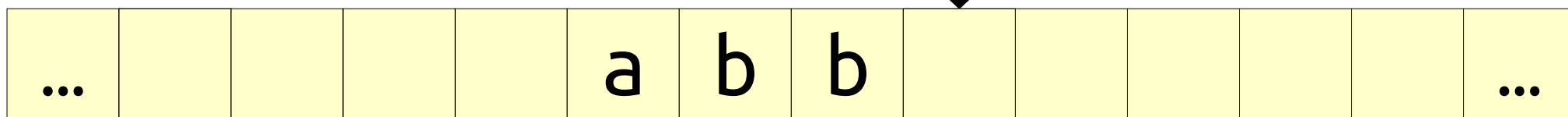
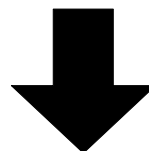
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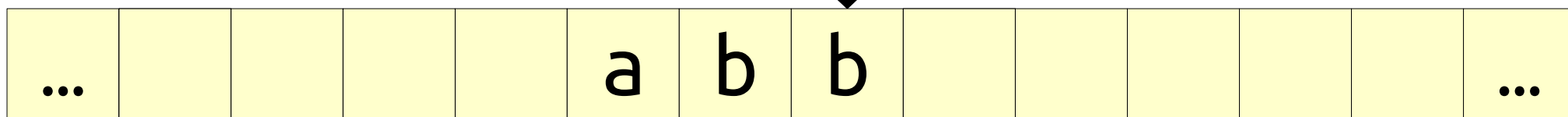
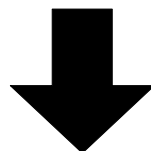
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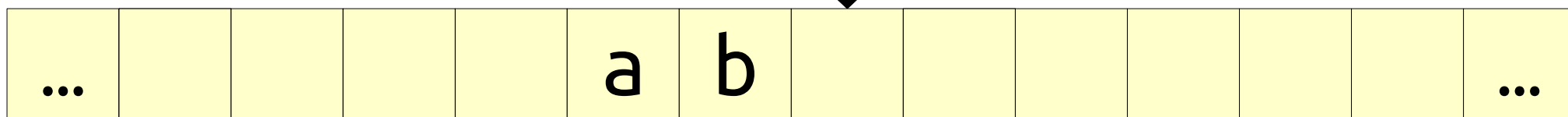
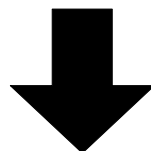
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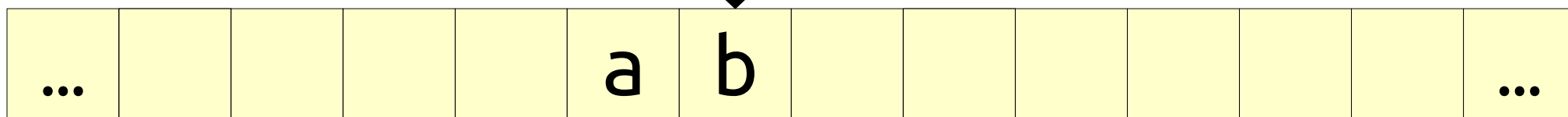
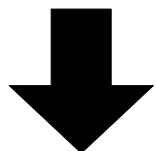
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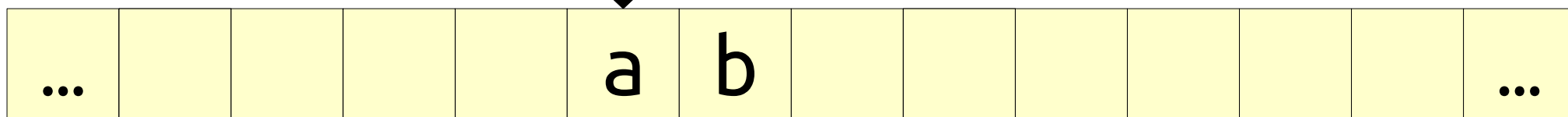
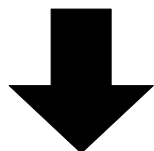
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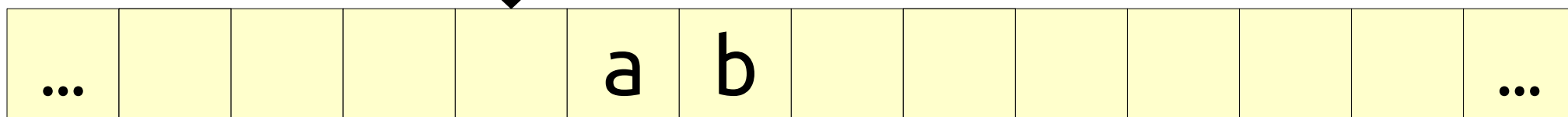
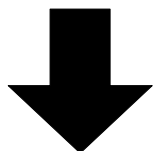
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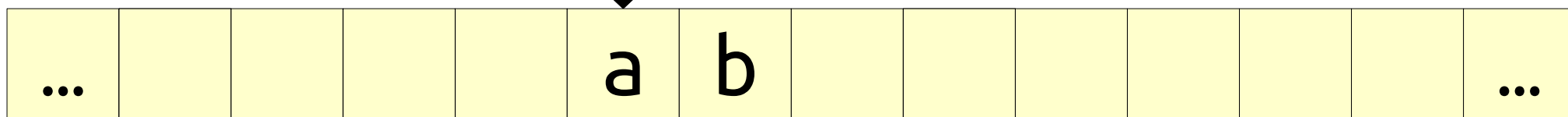
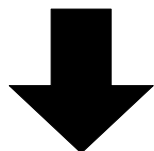
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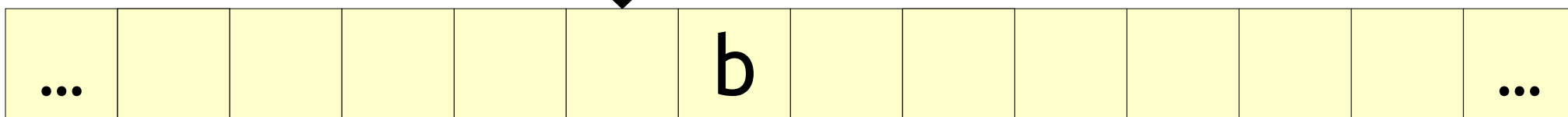
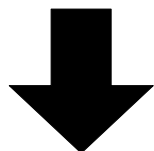
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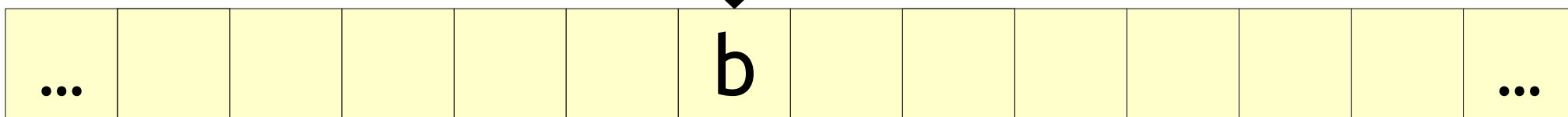
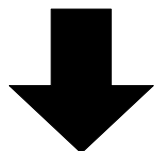
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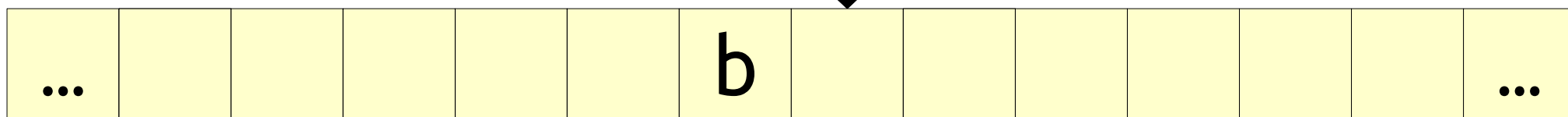
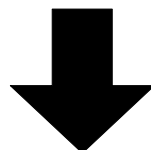
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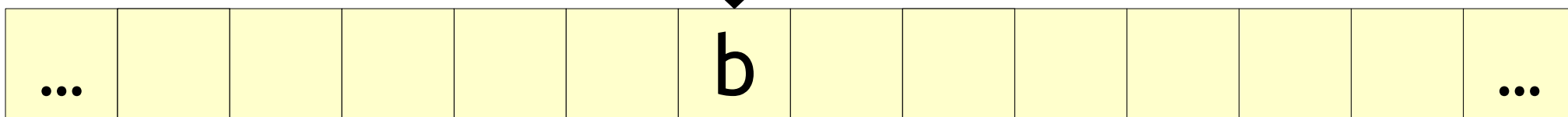
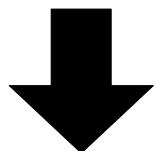
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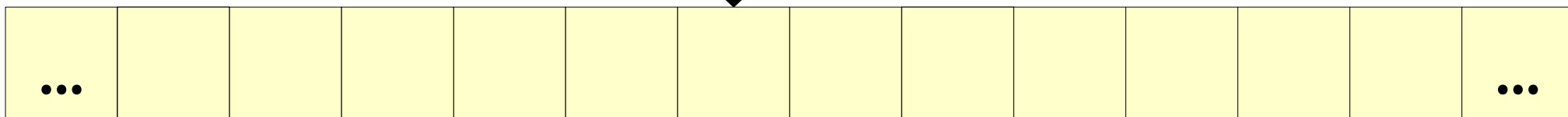
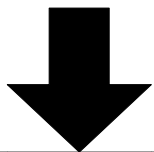
A Sketch of our TM

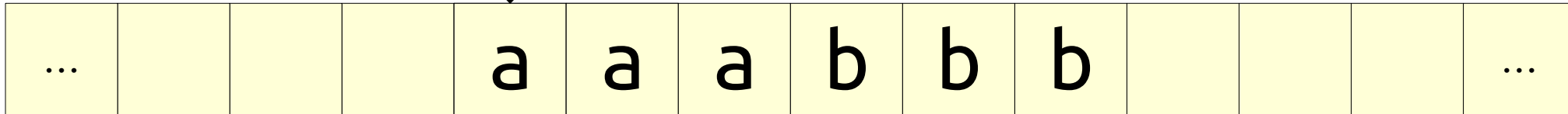
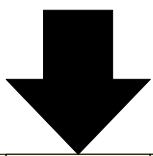


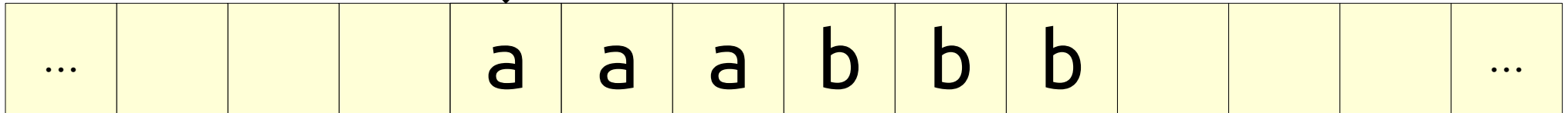
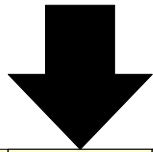
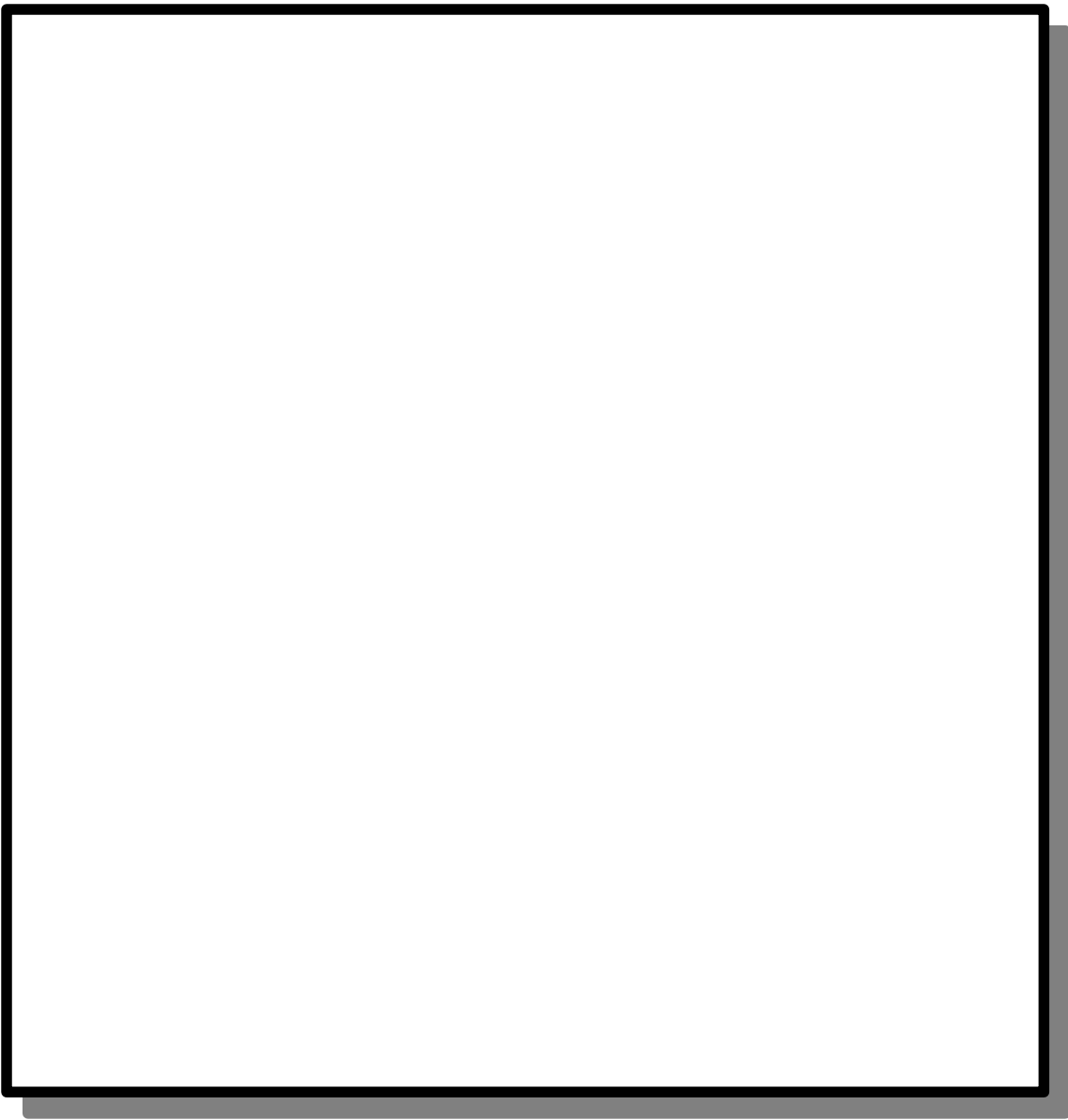
A Sketch of our TM



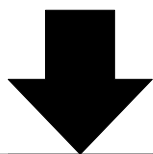
A Sketch of our TM







Start:



...

a

a

a

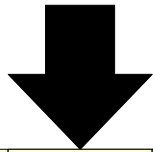
b

b

b

...

Start:



...

a

a

a

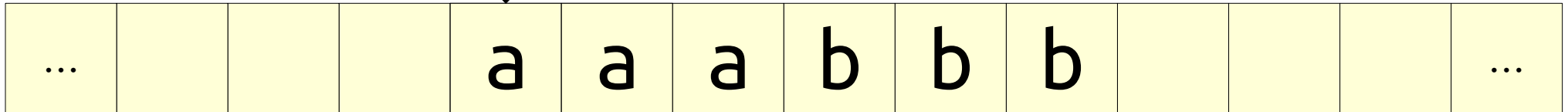
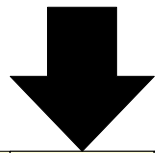
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b

b

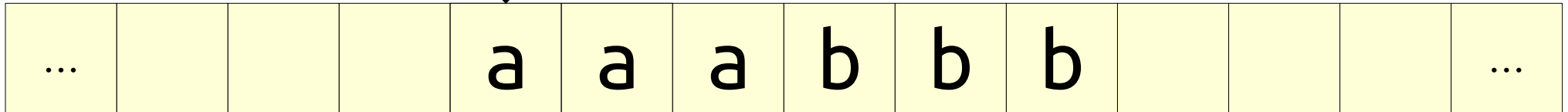
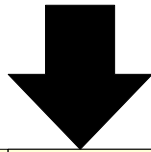
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Start:

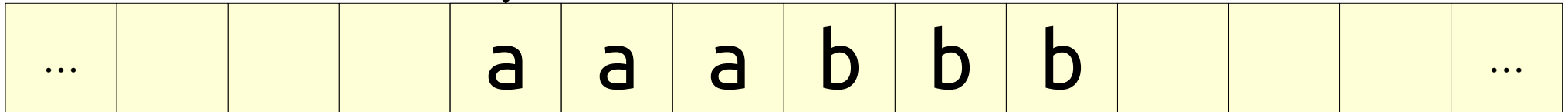
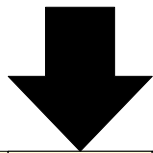


Start:

If Blank Return True



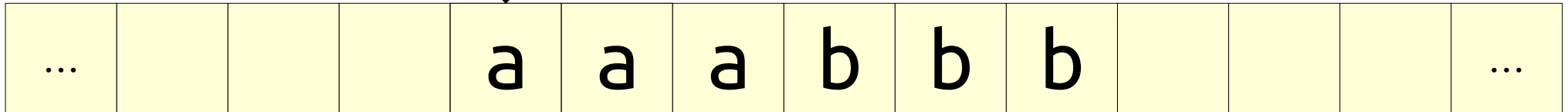
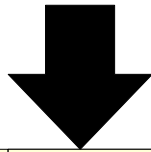
Start:
If Blank Return True



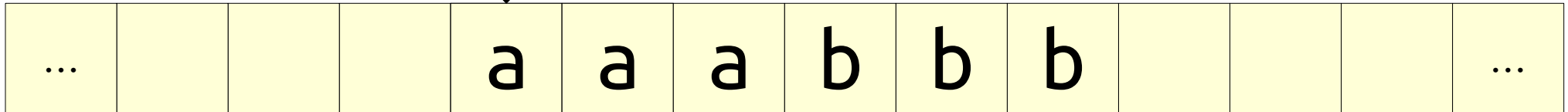
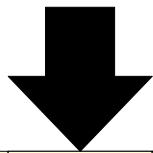
Start:

If Blank Return True

If 'b' Return False



Start:
If Blank Return True
If 'b' Return False

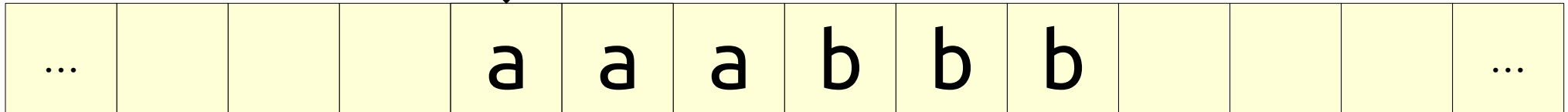
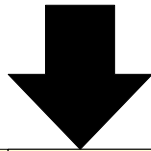


Start:

If Blank Return True

If 'b' Return False

Write Blank

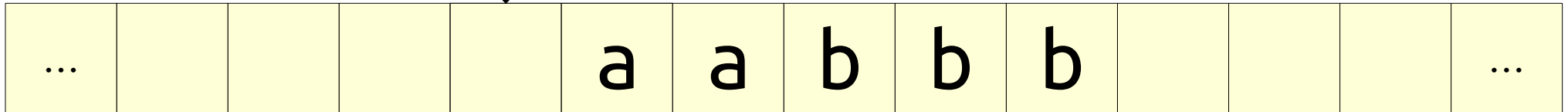
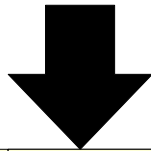


Start:

If Blank Return True

If 'b' Return False

Write Blank

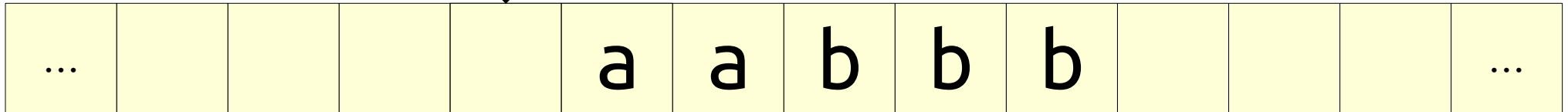
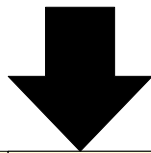


Start:

If Blank Return True

If 'b' Return False

Write Blank



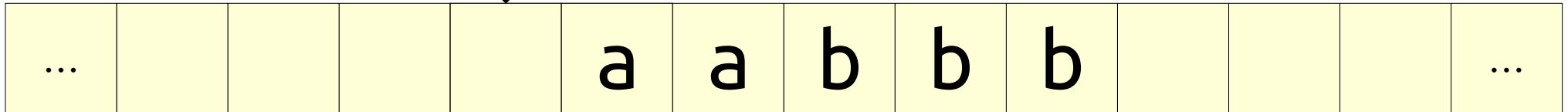
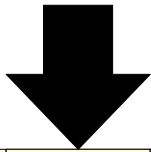
Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:



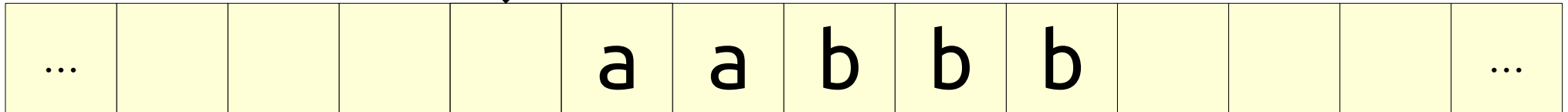
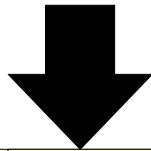
Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:



Start:

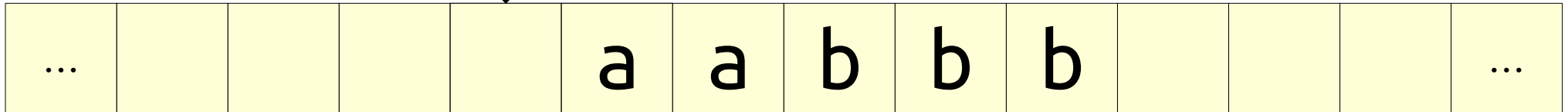
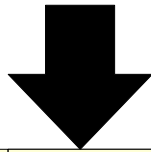
If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right



Start:

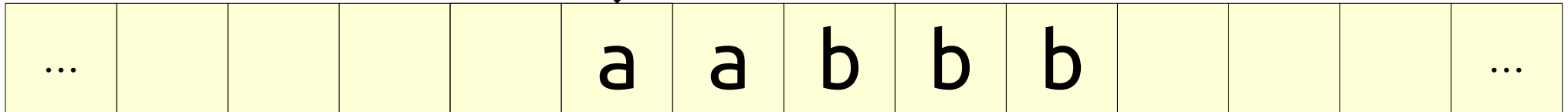
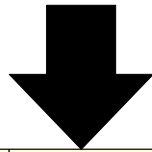
If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right



Start:

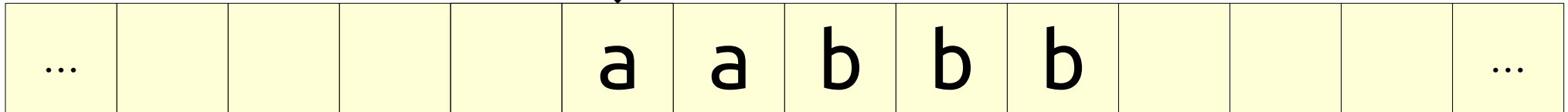
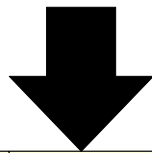
If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right



Start:

If Blank Return True

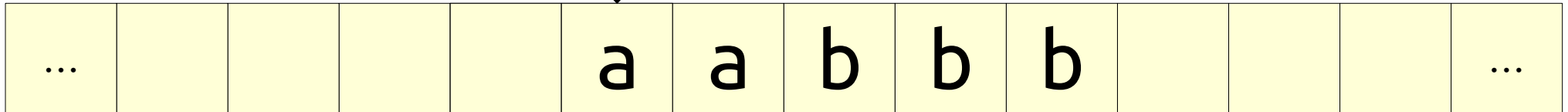
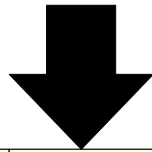
If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight



Start:

If Blank Return True

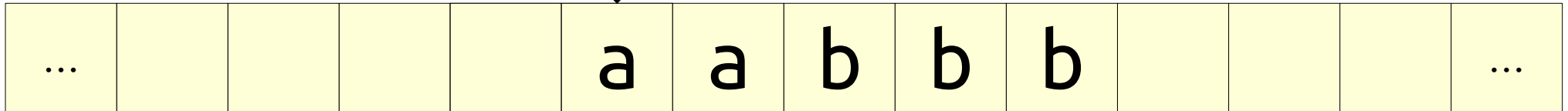
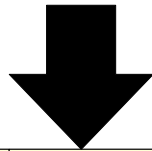
If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight



Start:

If Blank Return True

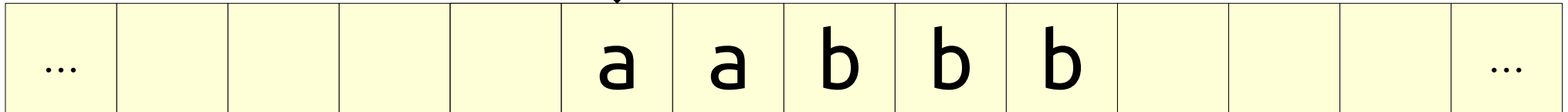
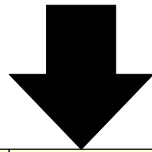
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ZipRight:

Move Right

If Not Blank Goto ZipRight



Start:

If Blank Return True

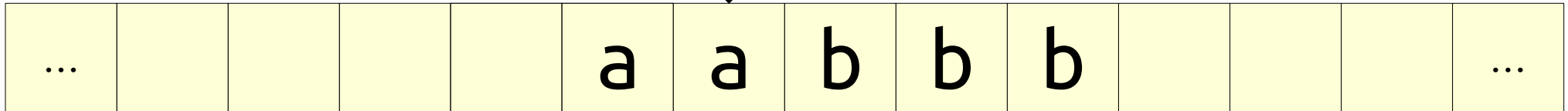
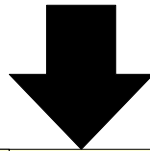
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Move Right

If Not Blank Goto ZipRight



Start:

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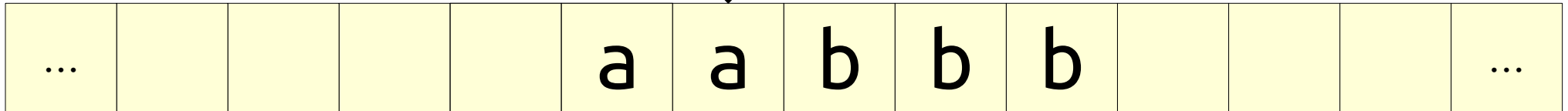
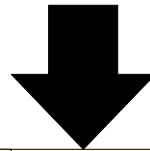
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Move Right

If Not Blank Goto ZipRight



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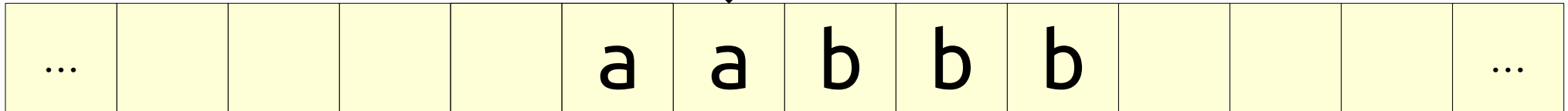
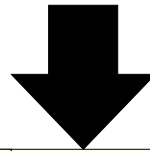
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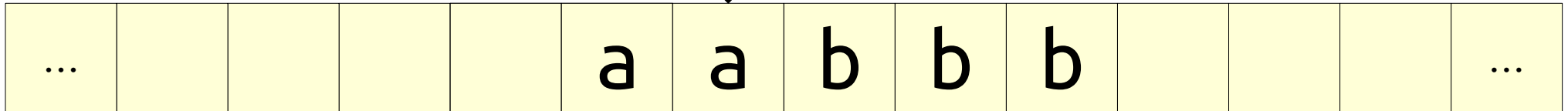
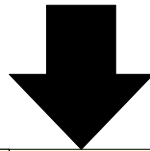
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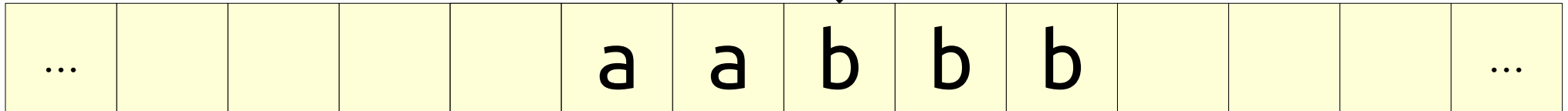
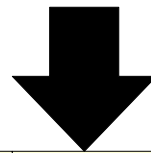
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Move Right

If Not Blank Goto ZipRight



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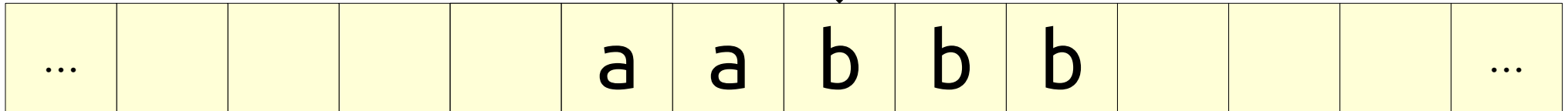
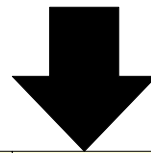
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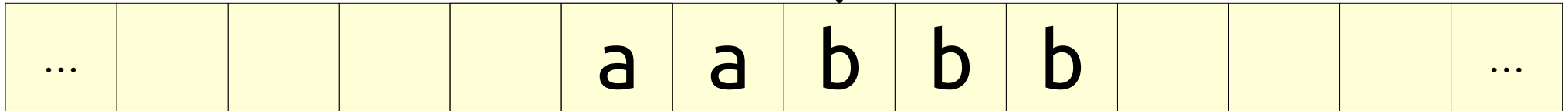
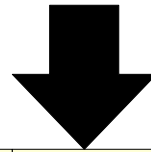
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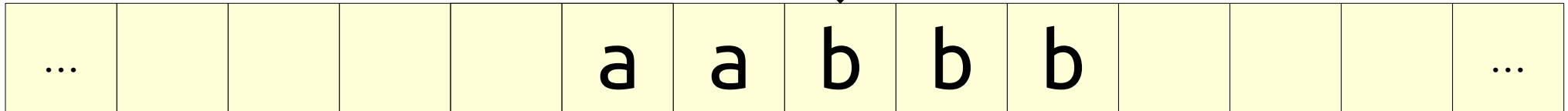
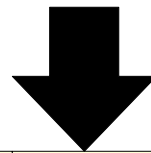
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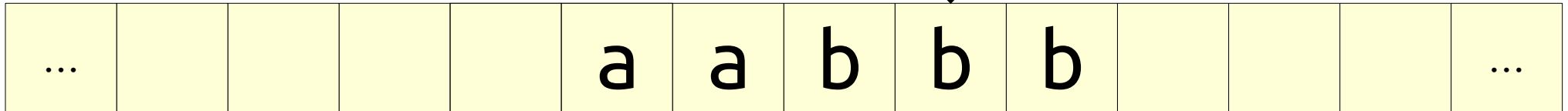
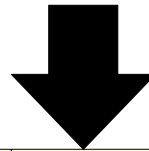
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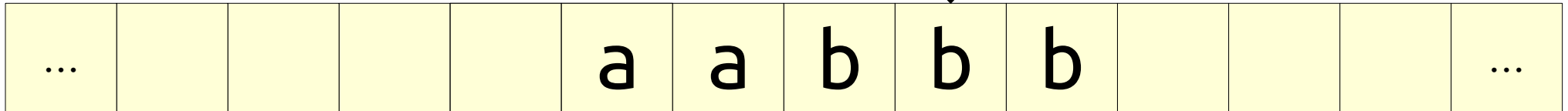
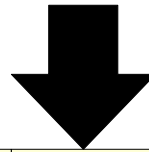
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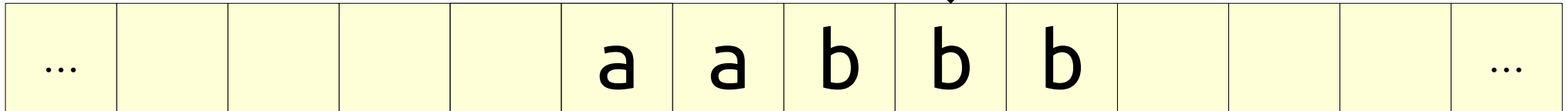
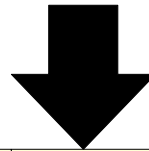
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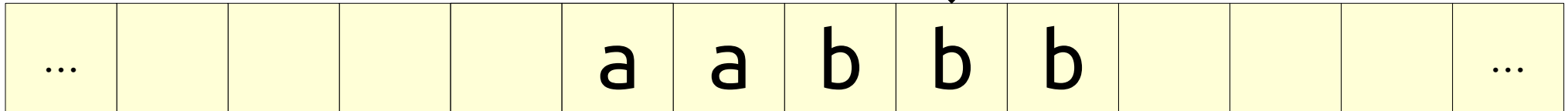
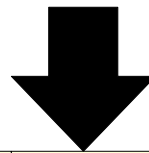
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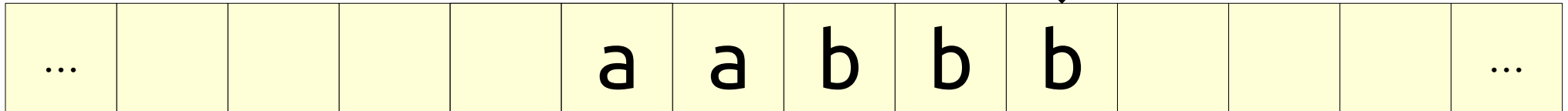
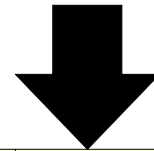
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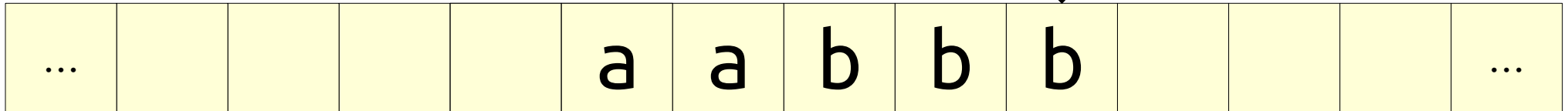
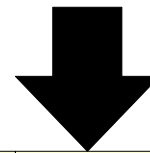
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If Not Blank Goto ZipRight



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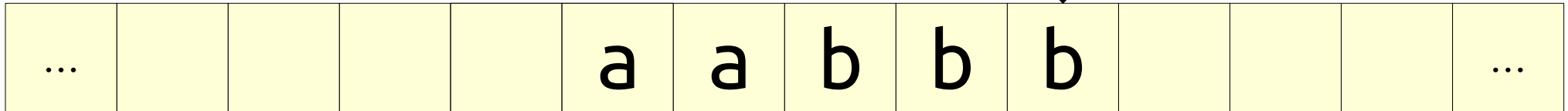
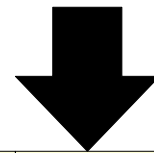
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If Not Blank Goto ZipRight



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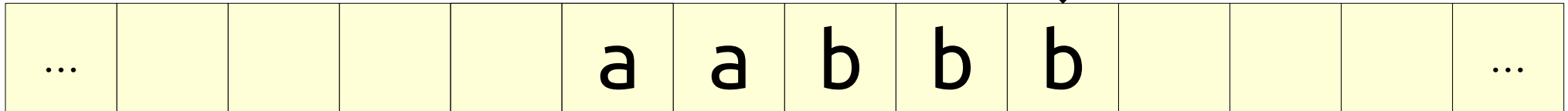
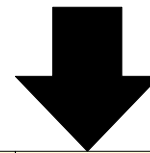
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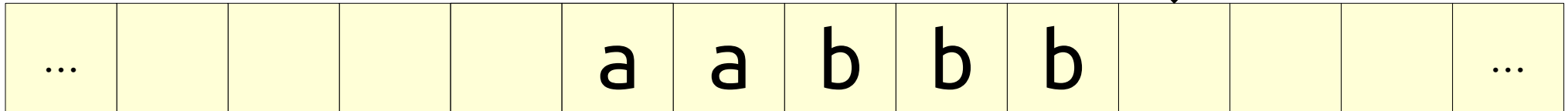
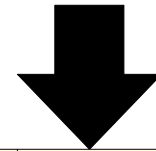
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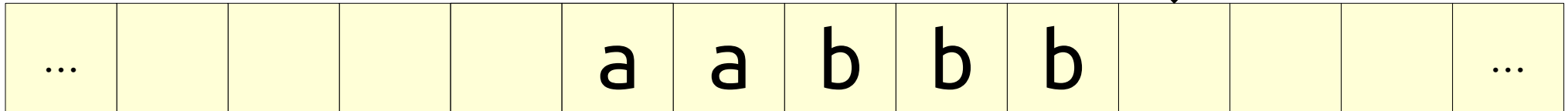
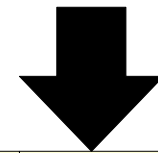
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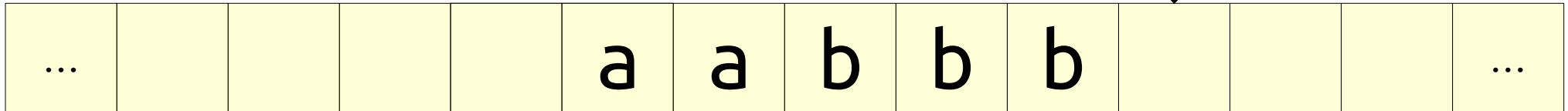
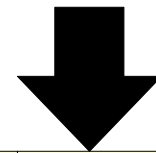
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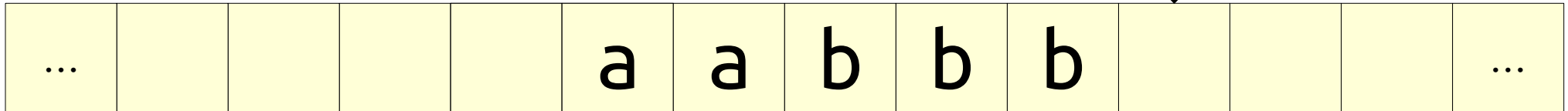
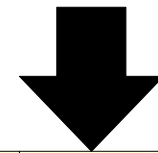
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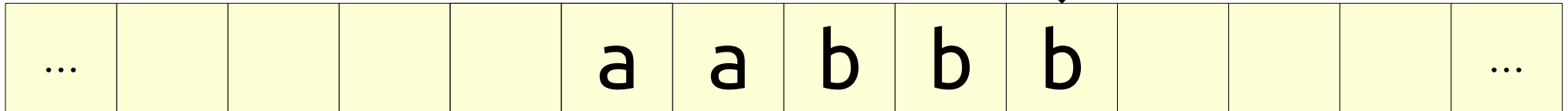
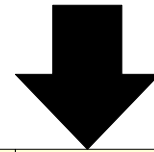
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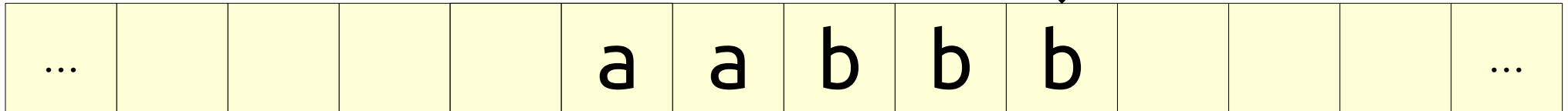
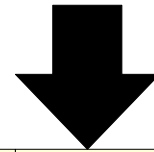
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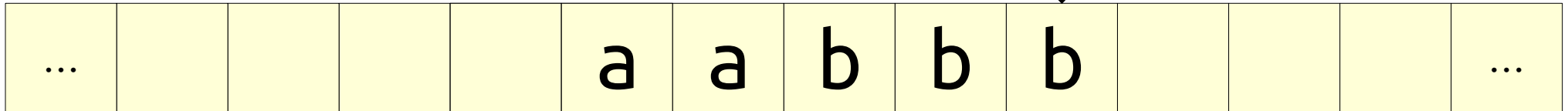
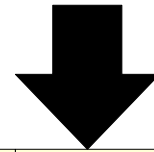
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If Not 'b' Return False



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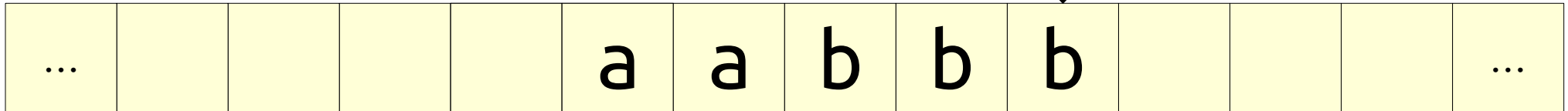
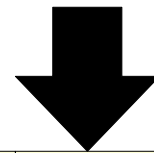
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If Not 'b' Return False



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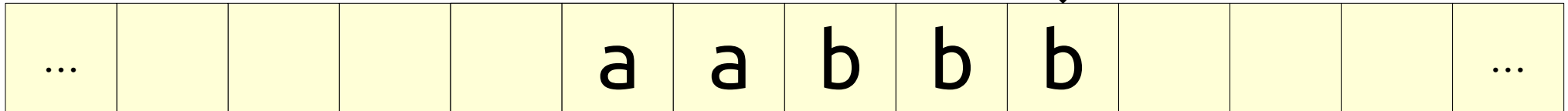
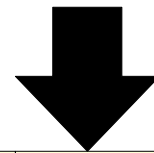
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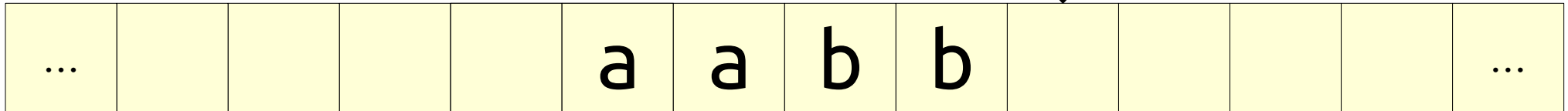
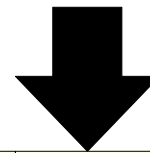
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Move Left

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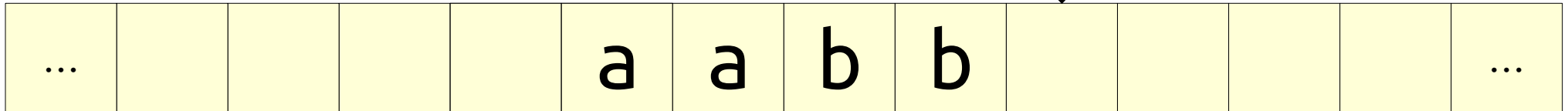
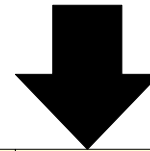
Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank



Start:

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Move Left

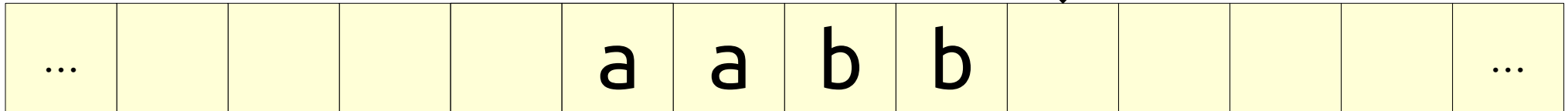
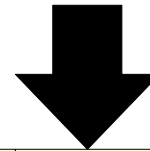
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Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

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ZipRight:

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If Not Blank Goto ZipRight

Move Left

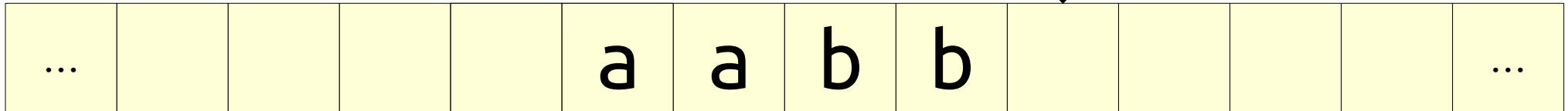
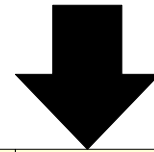
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If Not Blank Goto ZipLeft



Start:

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Move Left

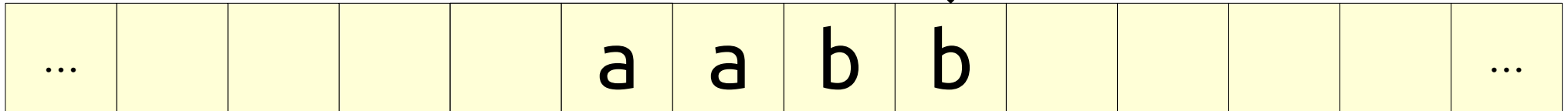
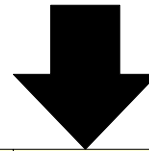
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If Not Blank Goto ZipLeft



Start:

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ZipRight:

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If Not Blank Goto ZipRight

Move Left

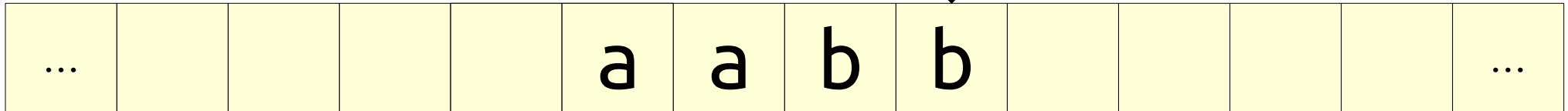
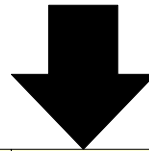
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Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

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ZipRight:

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If Not Blank Goto ZipRight

Move Left

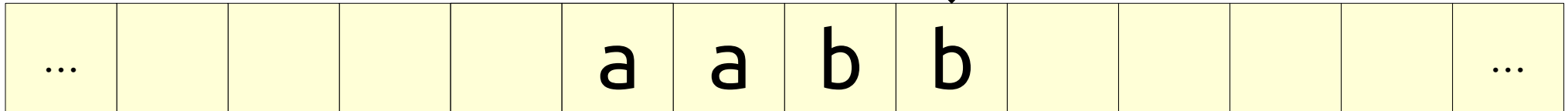
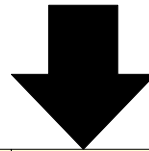
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If Not Blank Goto ZipLeft



Start:

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ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

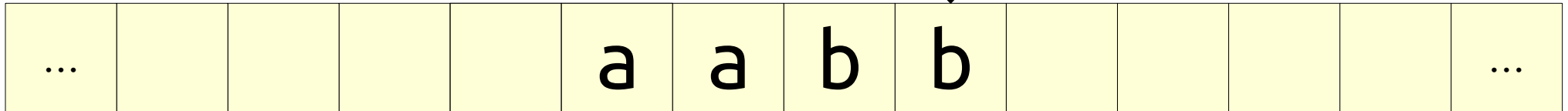
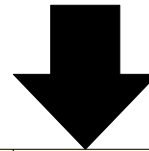
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If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

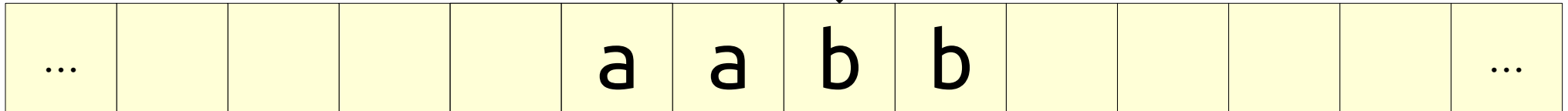
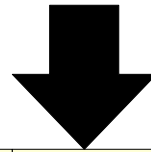
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Move Left

If Not Blank Goto ZipLeft



Start:

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If 'b' Return False

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ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

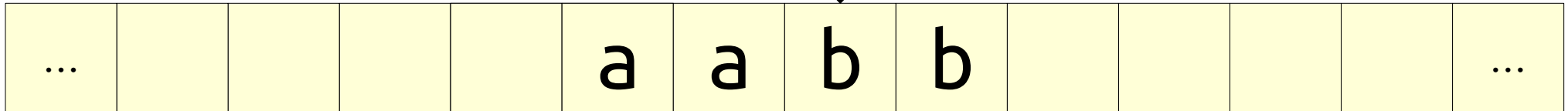
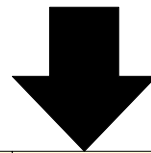
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If Not Blank Goto ZipLeft



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Move Left

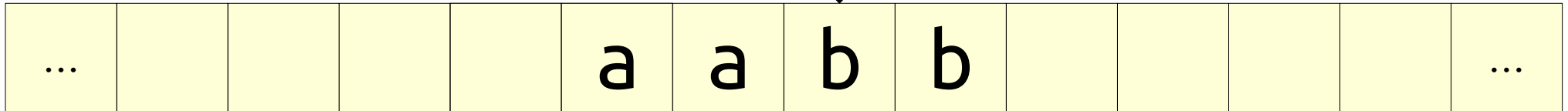
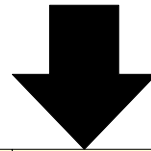
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Start:

If Blank Return True

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ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

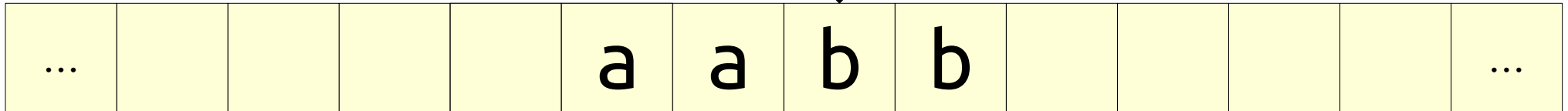
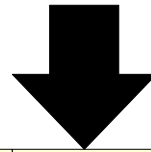
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

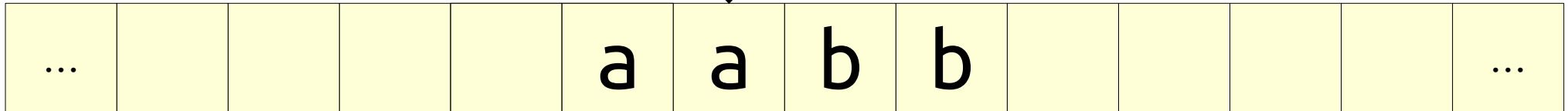
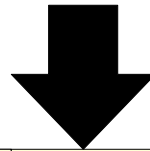
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

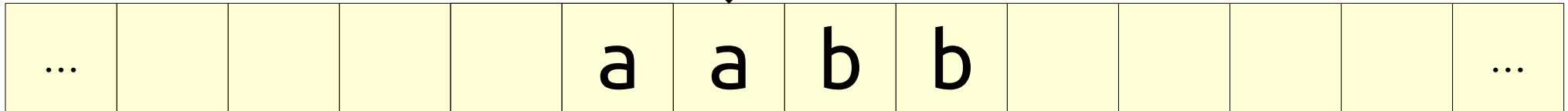
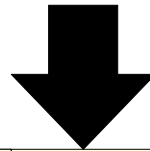
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

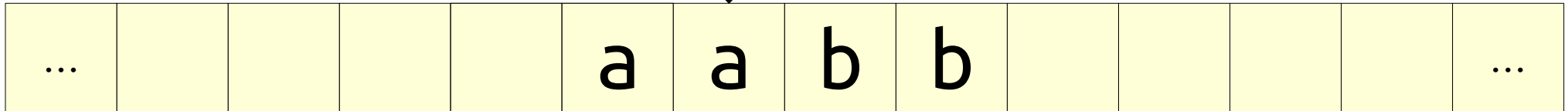
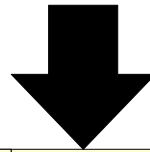
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

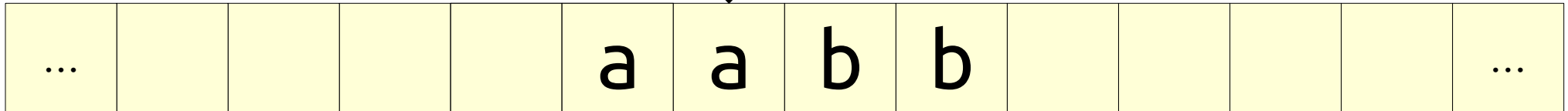
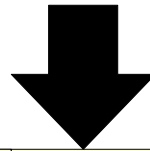
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

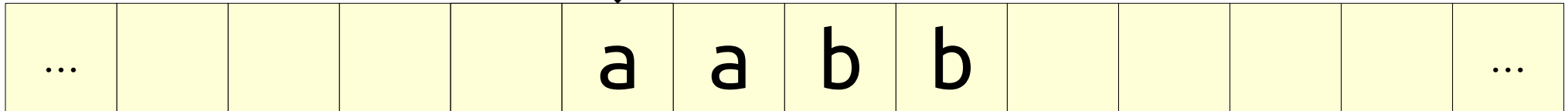
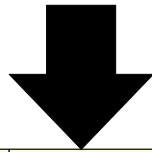
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

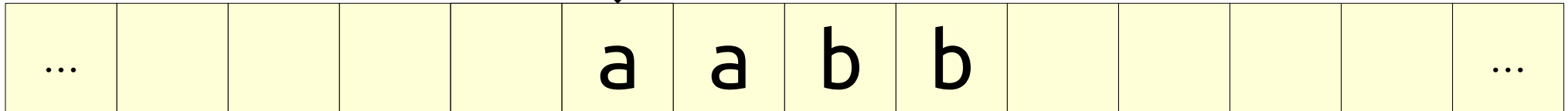
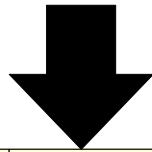
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

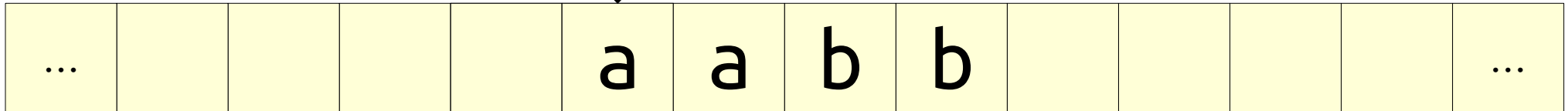
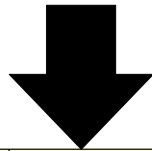
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

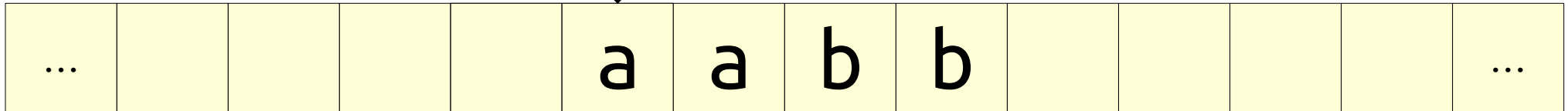
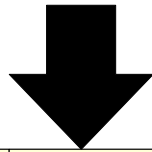
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Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

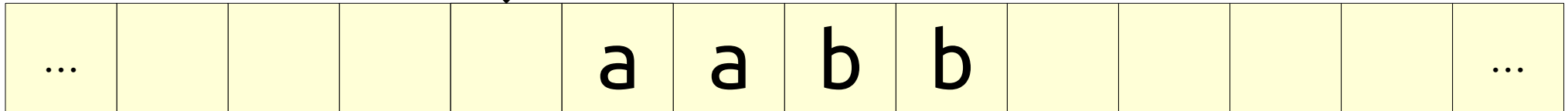
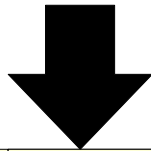
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

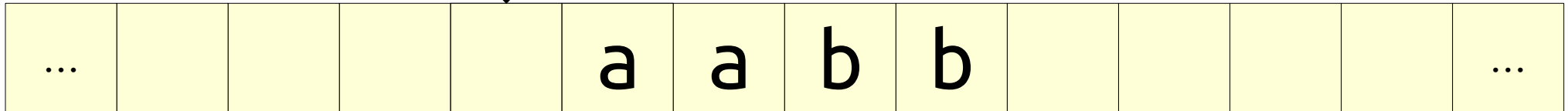
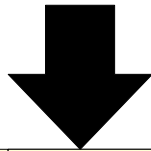
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

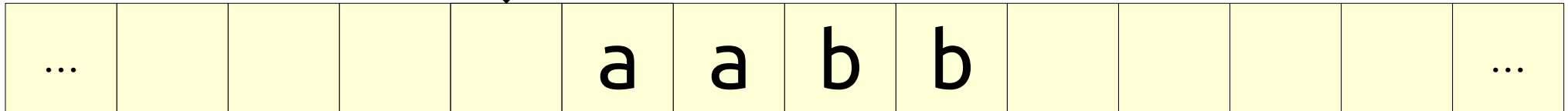
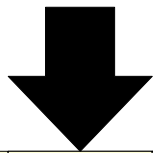
If Not 'b' Return False

Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

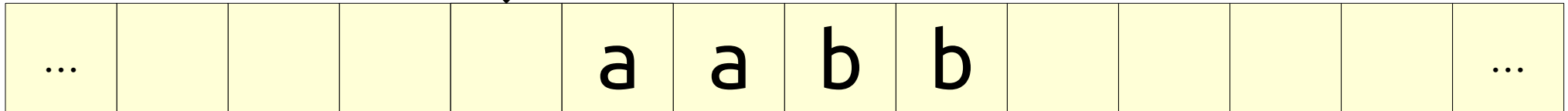
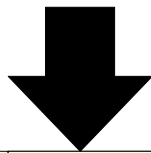
Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

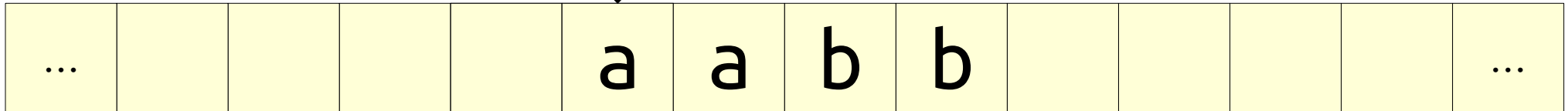
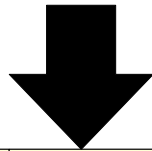
Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

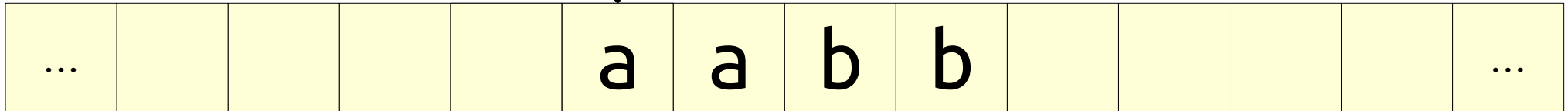
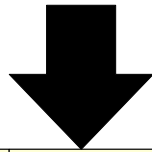
Write Blank

ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

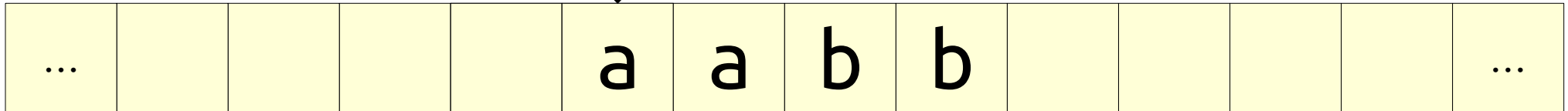
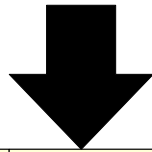
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

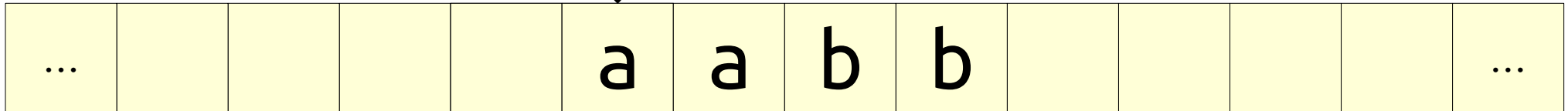
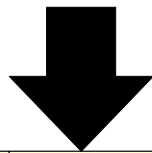
```
If Blank Return True  
If 'b' Return False  
Write Blank
```

ZipRight:

```
Move Right  
If Not Blank Goto ZipRight  
Move Left  
If Not 'b' Return False  
Write Blank
```

ZipLeft:

```
Move Left  
If Not Blank Goto ZipLeft  
Move Right  
Goto Start
```



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

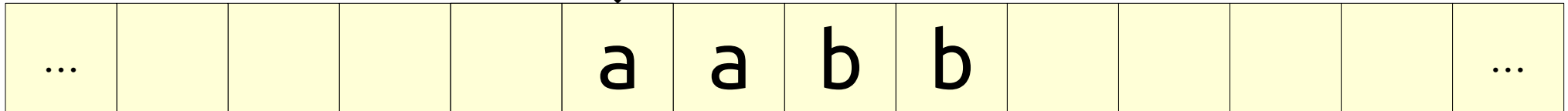
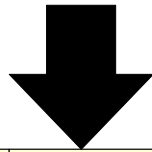
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

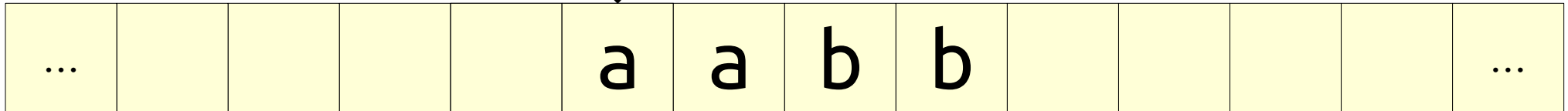
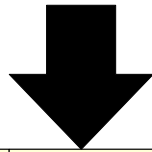
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

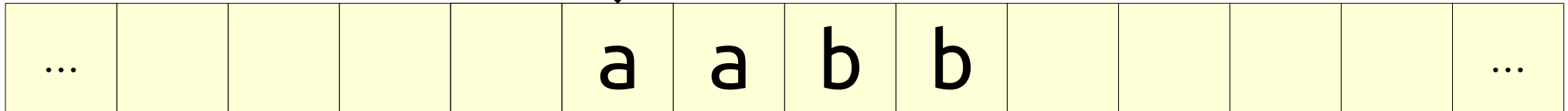
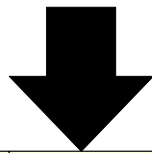
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

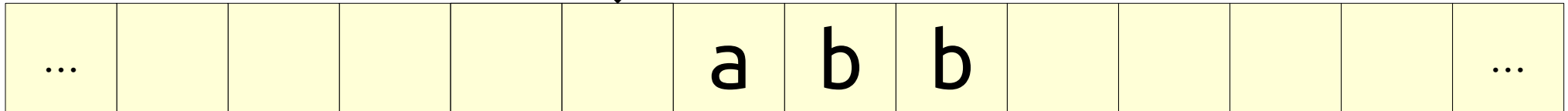
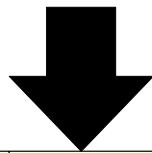
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

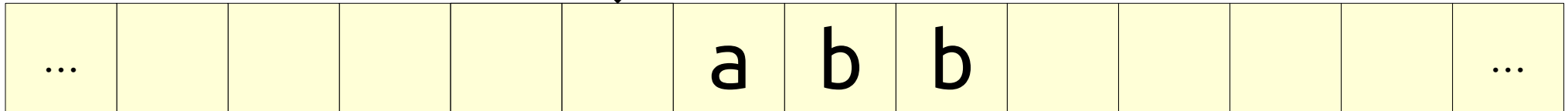
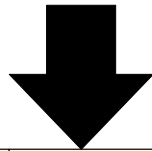
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

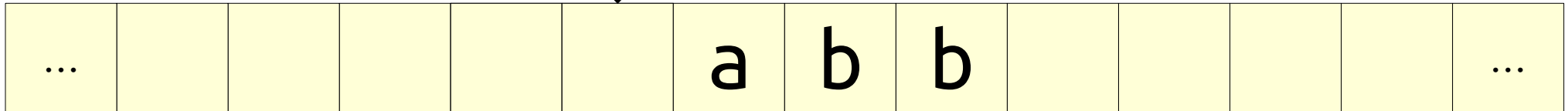
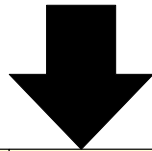
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

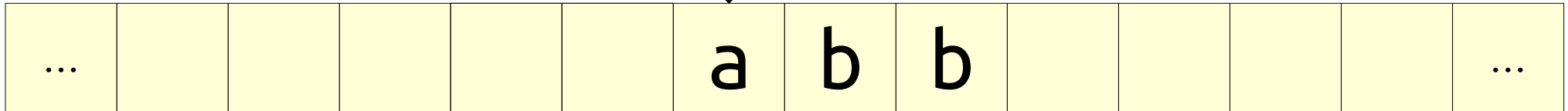
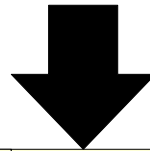
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

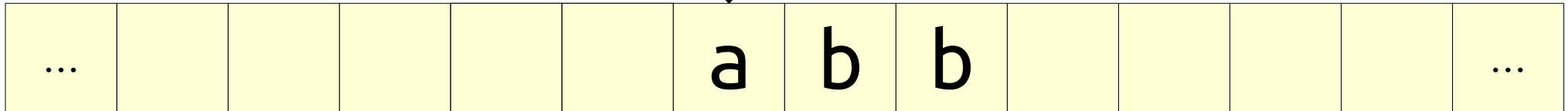
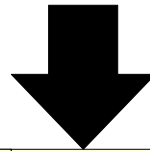
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

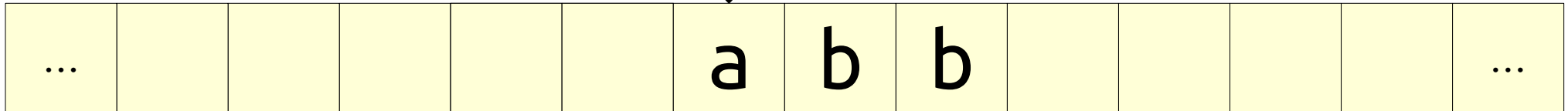
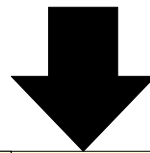
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

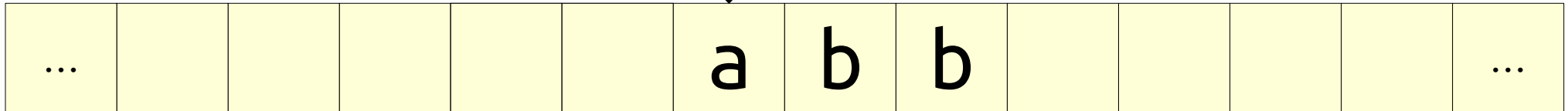
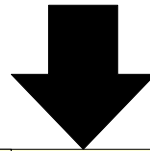
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

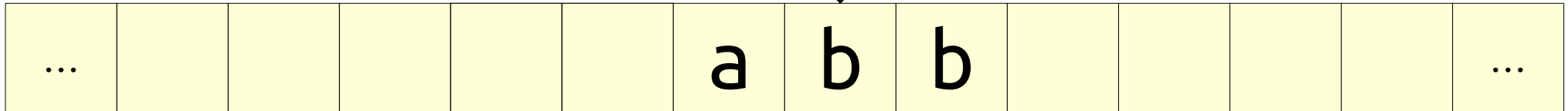
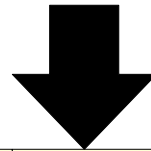
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

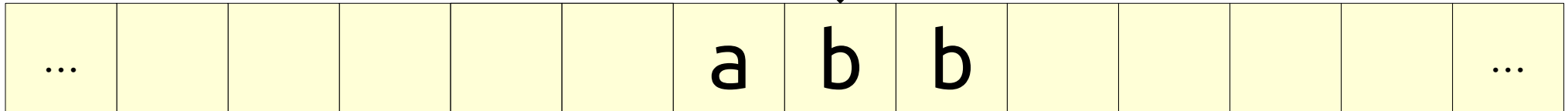
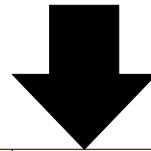
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

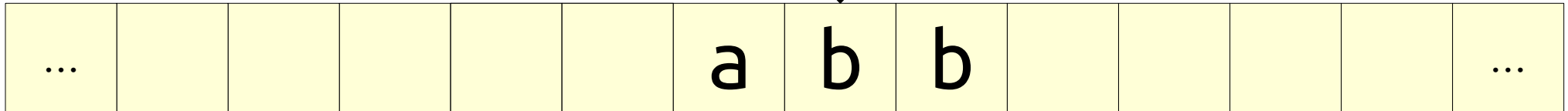
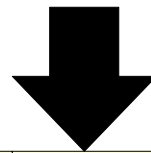
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

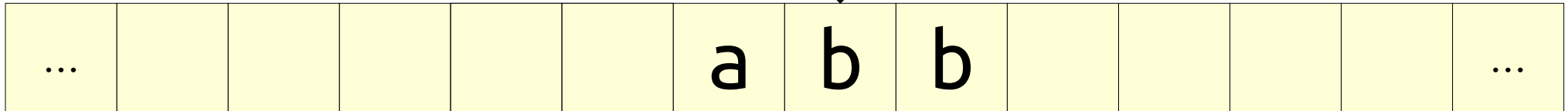
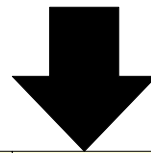
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

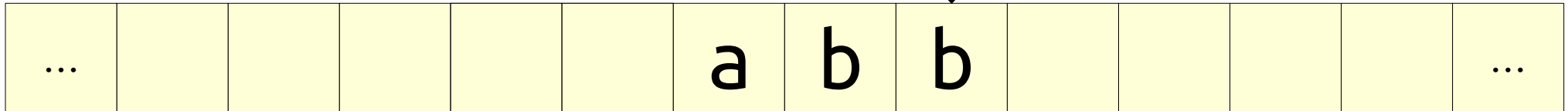
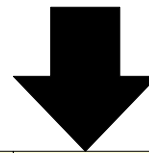
ZipLeft:

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If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

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If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

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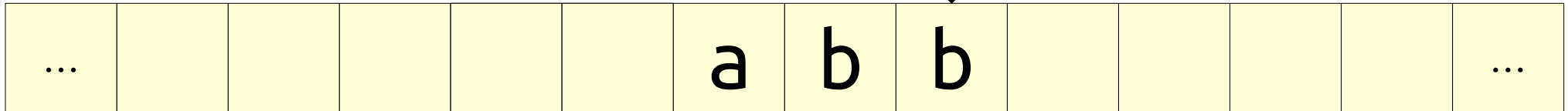
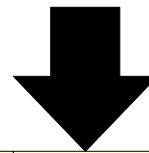
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

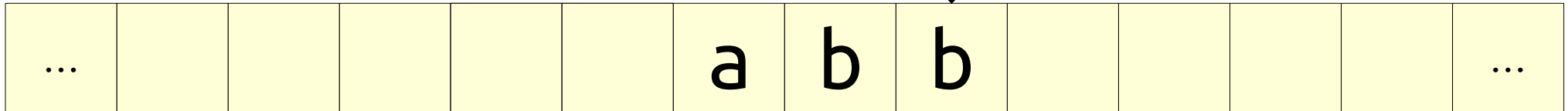
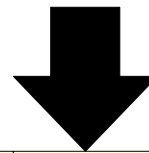
ZipLeft:

Move Left

If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

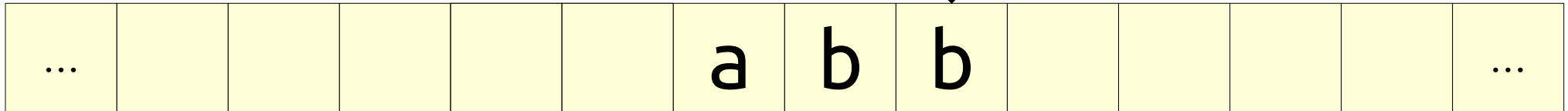
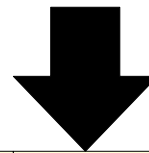
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If Not Blank Goto ZipLeft

Move Right

Goto Start



Start:

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If 'b' Return False

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ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

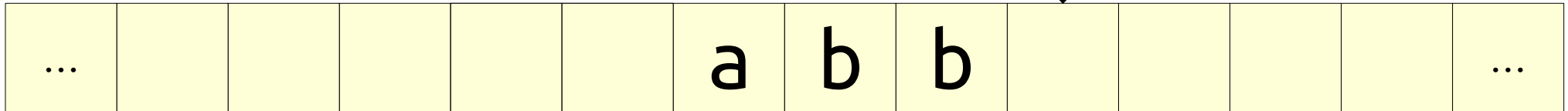
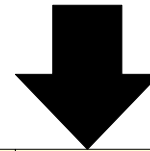
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If Not Blank Goto ZipLeft

Move Right

Goto Start



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If 'b' Return False

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ZipRight:

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If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

Write Blank

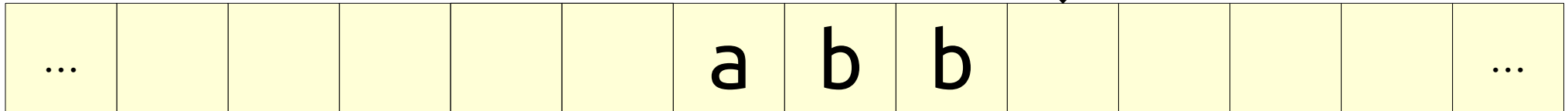
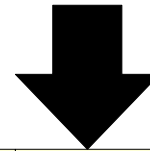
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If Not Blank Goto ZipLeft

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Goto Start



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If 'b' Return False

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ZipRight:

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If Not Blank Goto ZipRight

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If Not 'b' Return False

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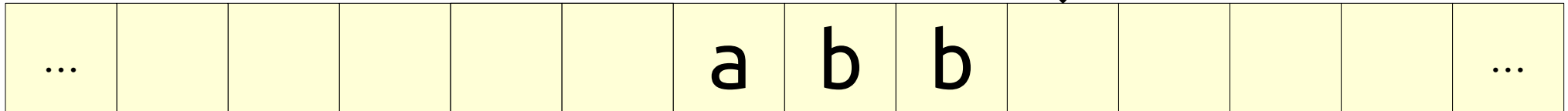
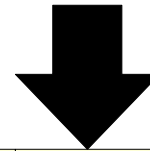
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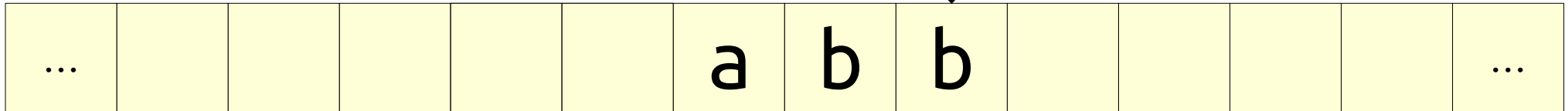
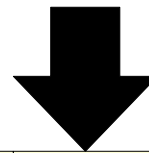
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Goto Start



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If Not 'b' Return False

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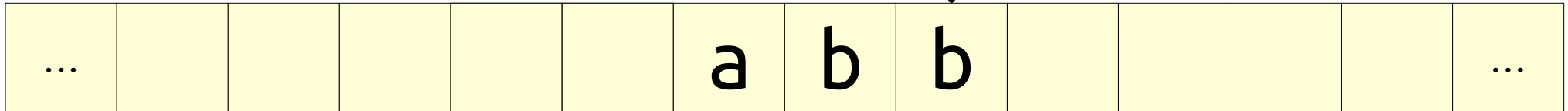
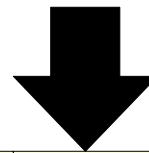
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If Not Blank Goto ZipRight

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If Not 'b' Return False

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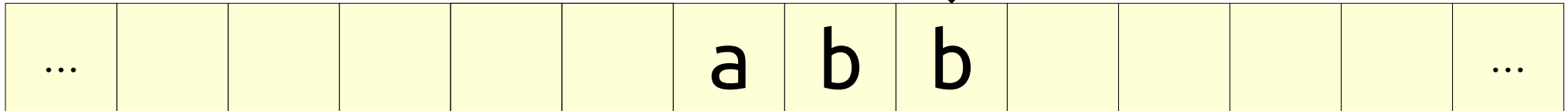
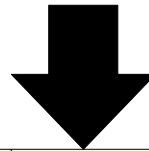
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If Not 'b' Return False

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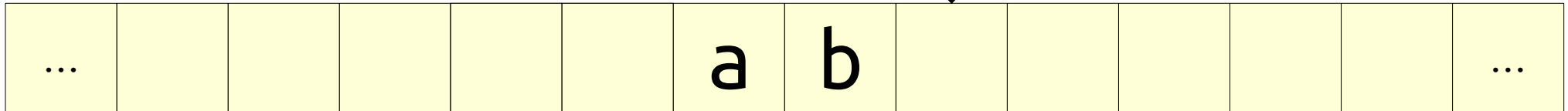
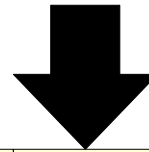
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If Not 'b' Return False

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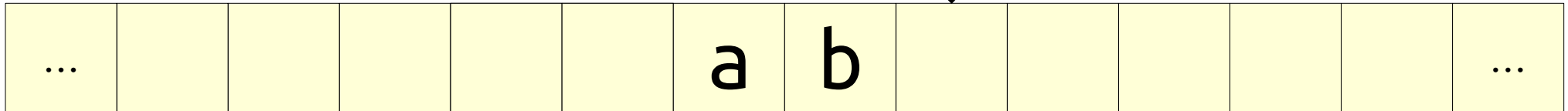
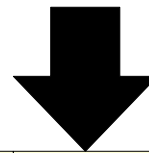
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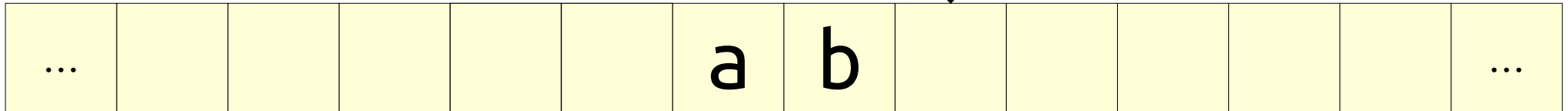
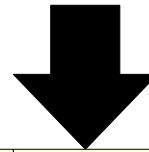
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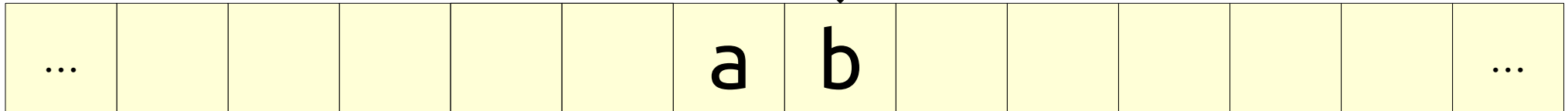
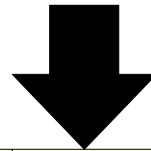
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If 'b' Return False

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ZipRight:

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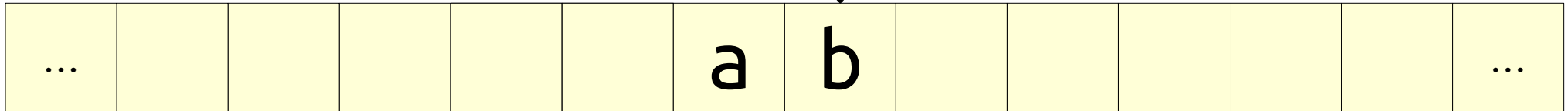
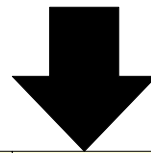
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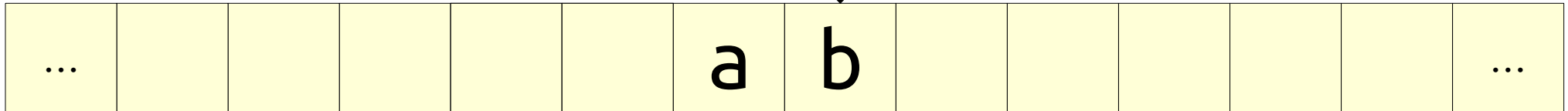
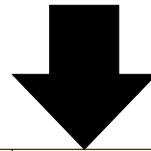
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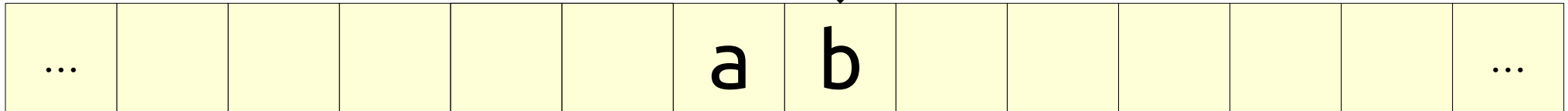
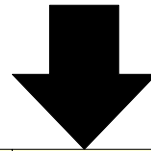
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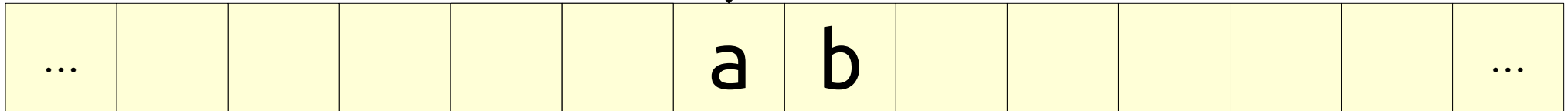
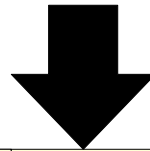
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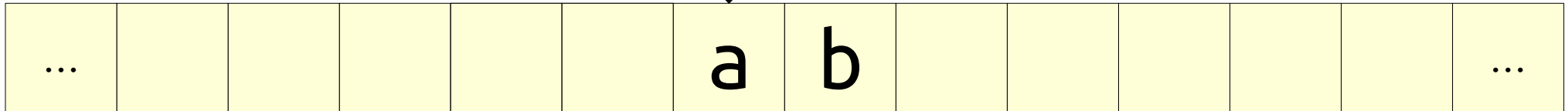
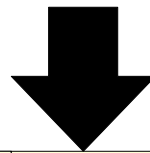
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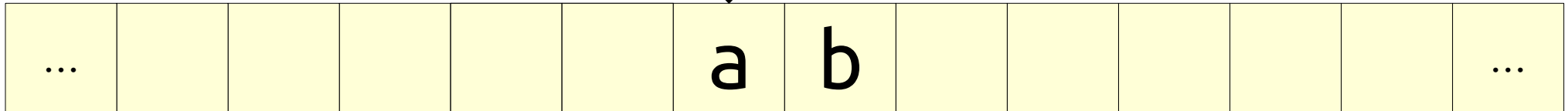
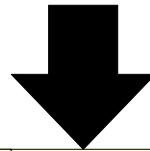
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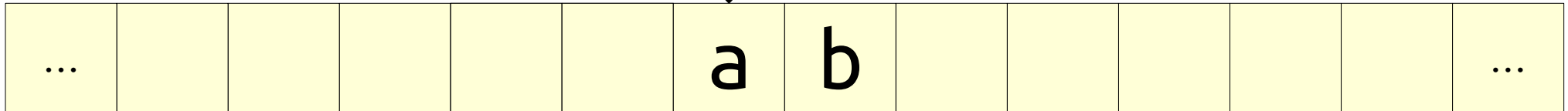
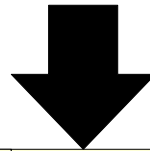
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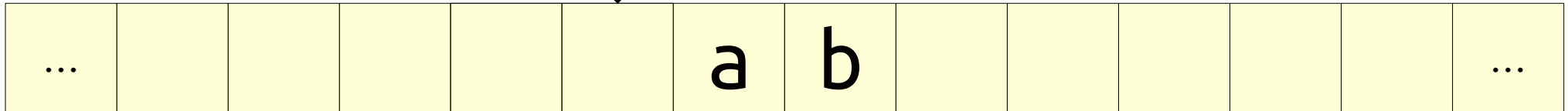
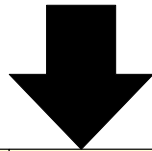
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If Not Blank Goto ZipLeft

Move Right

Goto Start



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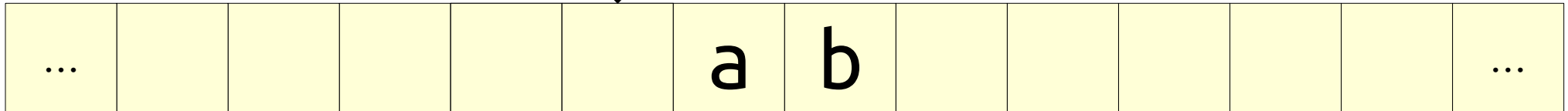
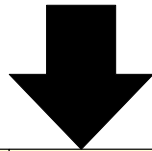
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Goto Start



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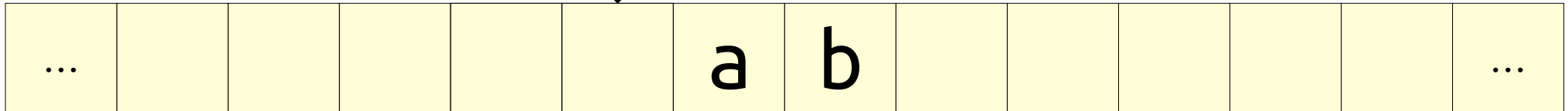
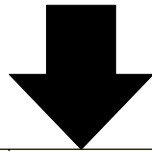
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If 'b' Return False

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If Not 'b' Return False

Write Blank

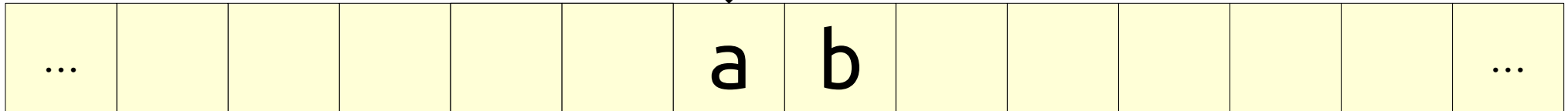
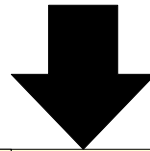
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If Not Blank Goto ZipLeft

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Goto Start



Start:

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If 'b' Return False

Write Blank

ZipRight:

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Write Blank

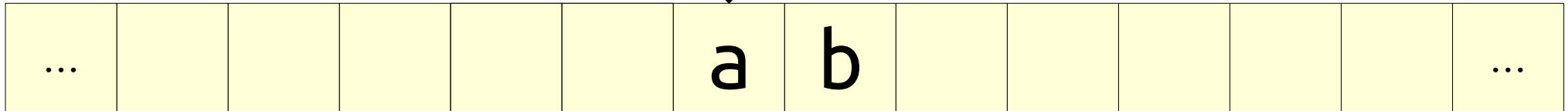
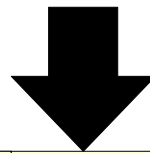
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Move Right

Goto Start



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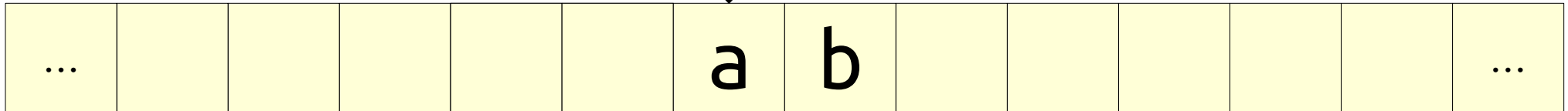
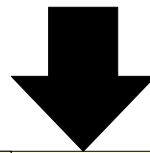
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If Blank Return True  
If 'b' Return False  
Write Blank
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ZipRight:

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Move Right  
If Not Blank Goto ZipRight  
Move Left  
If Not 'b' Return False  
Write Blank
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ZipLeft:

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Move Left  
If Not Blank Goto ZipLeft  
Move Right  
Goto Start
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Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

Move Left

If Not 'b' Return False

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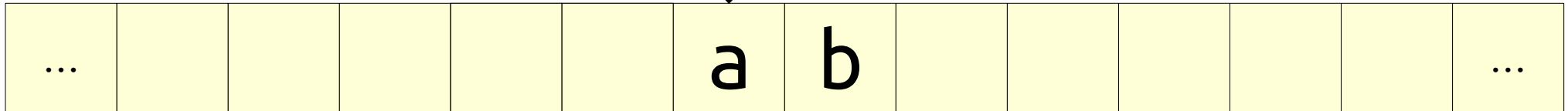
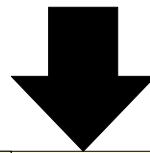
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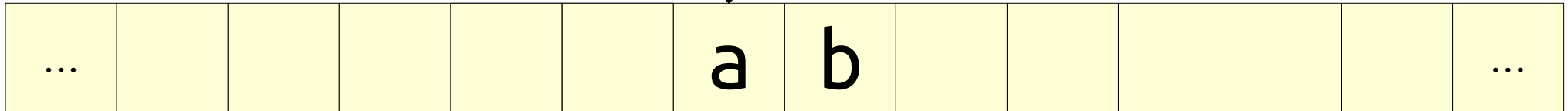
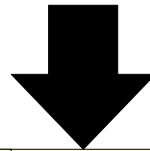
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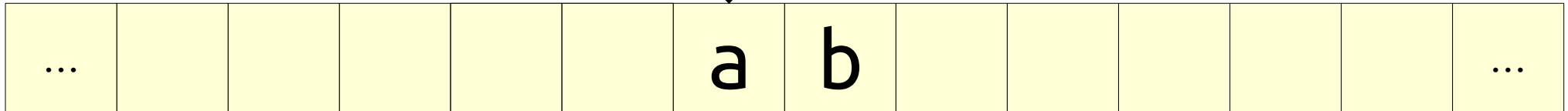
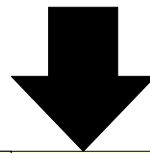
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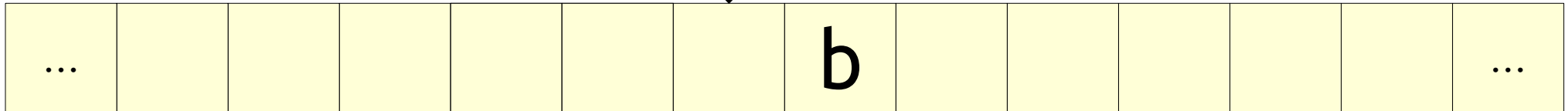
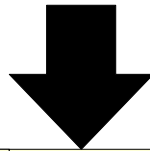
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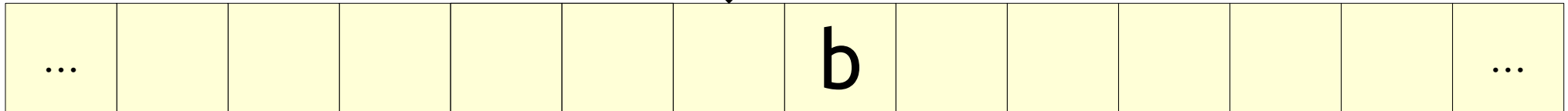
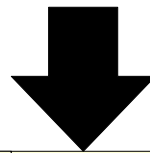
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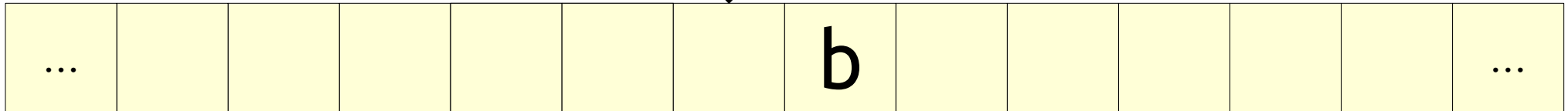
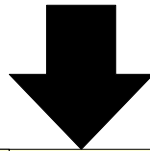
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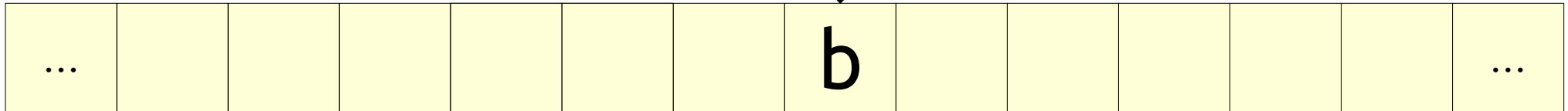
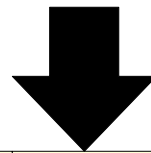
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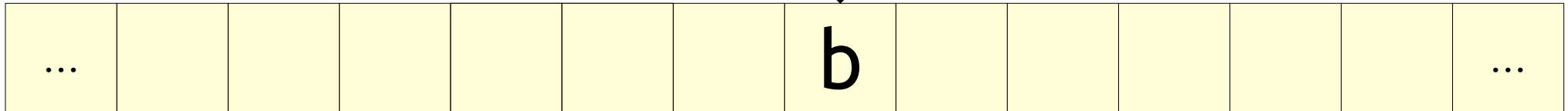
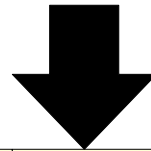
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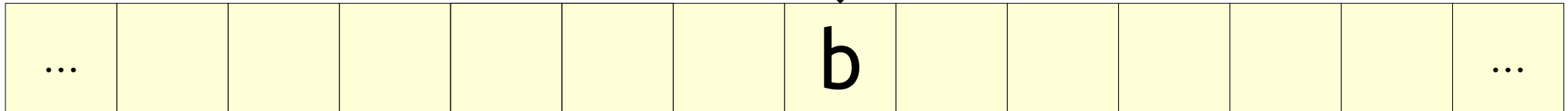
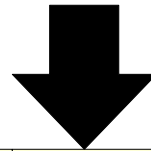
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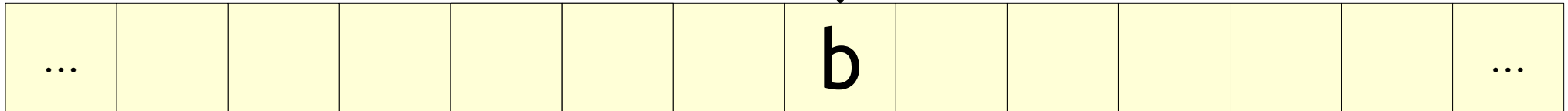
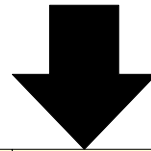
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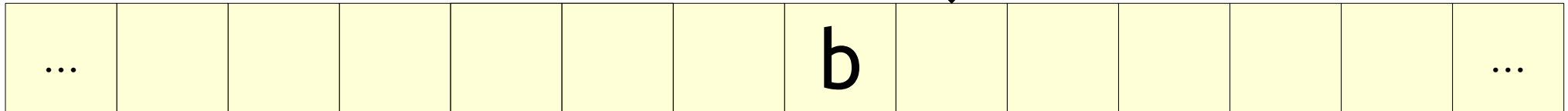
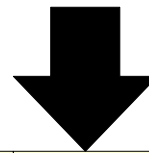
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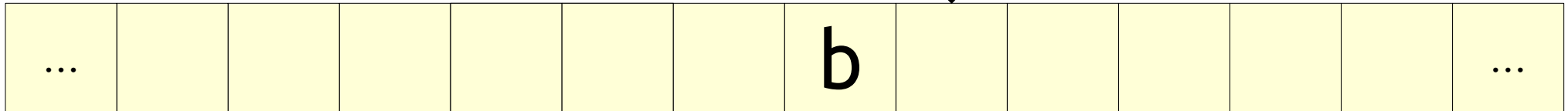
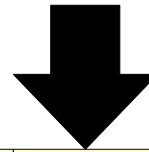
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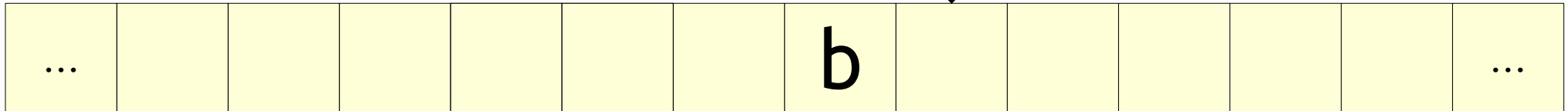
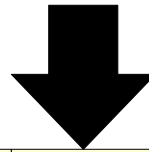
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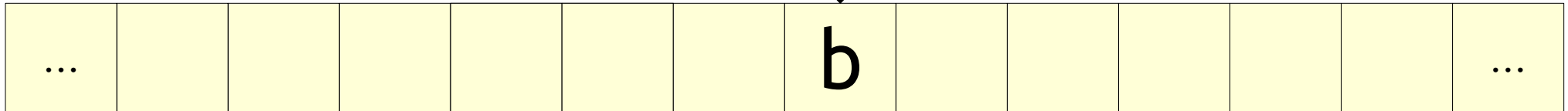
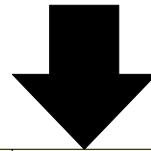
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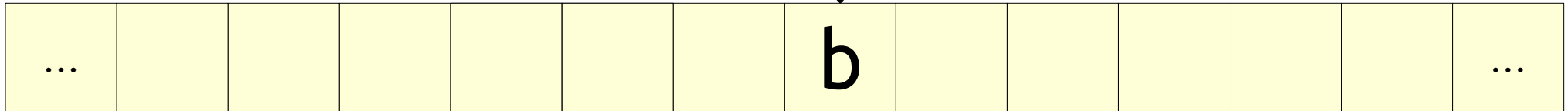
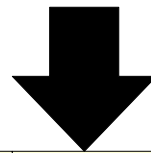
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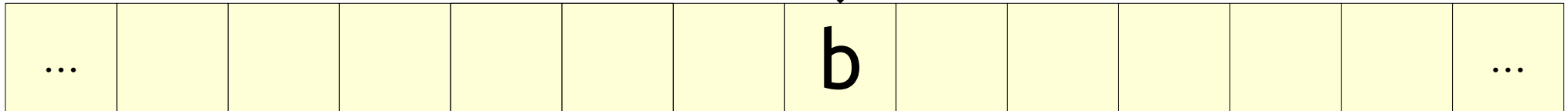
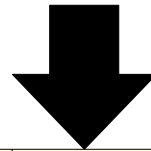
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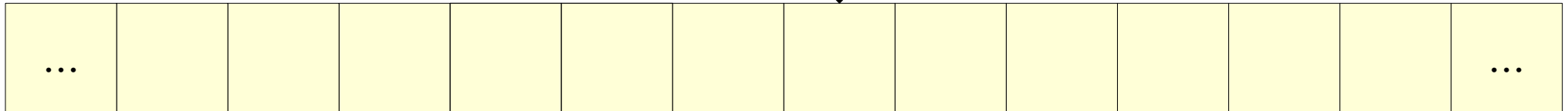
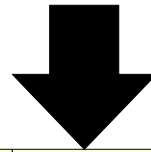
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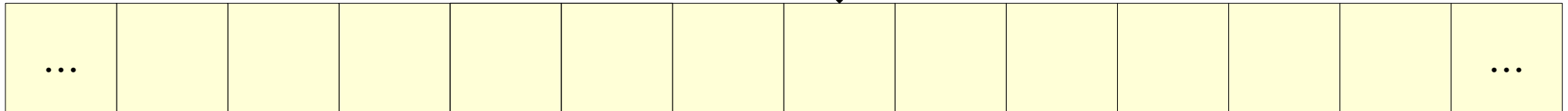
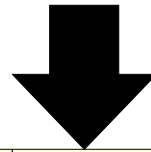
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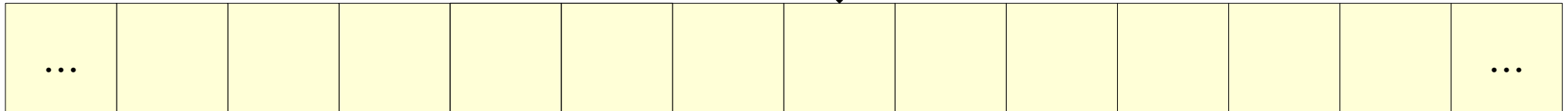
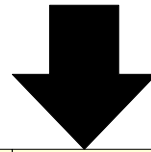
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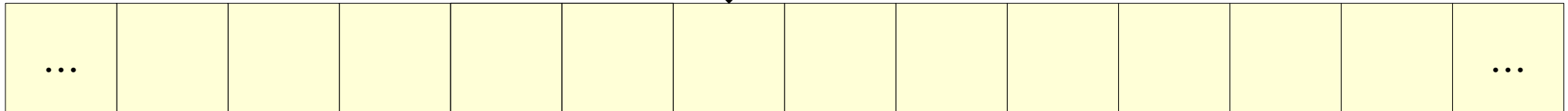
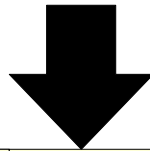
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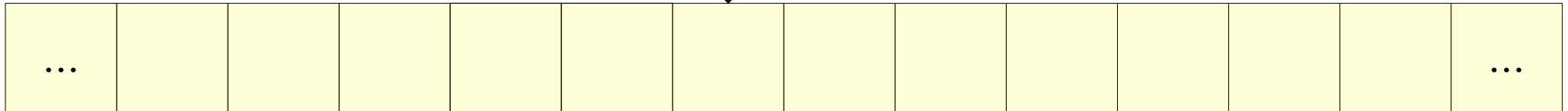
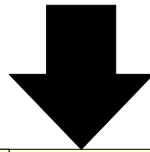
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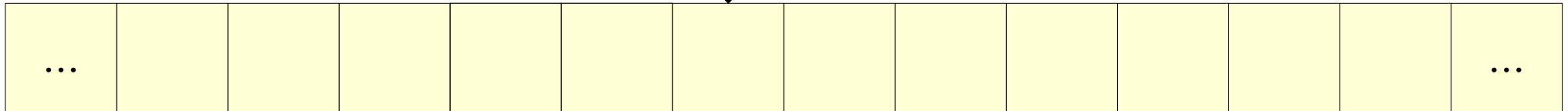
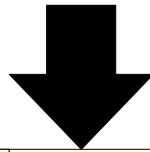
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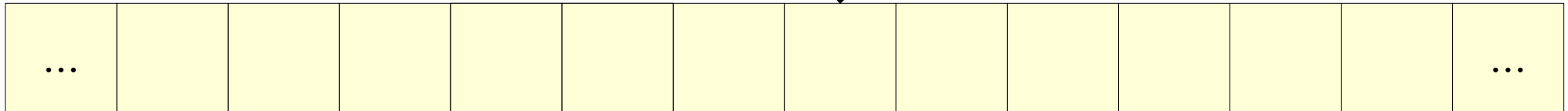
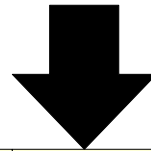
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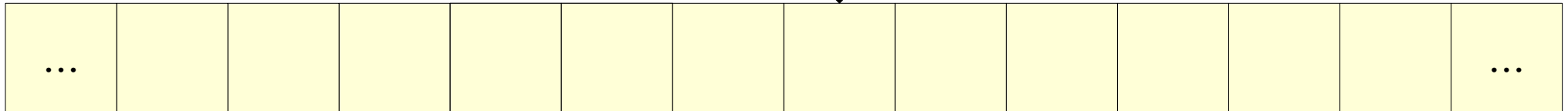
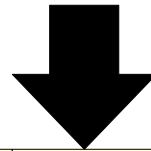
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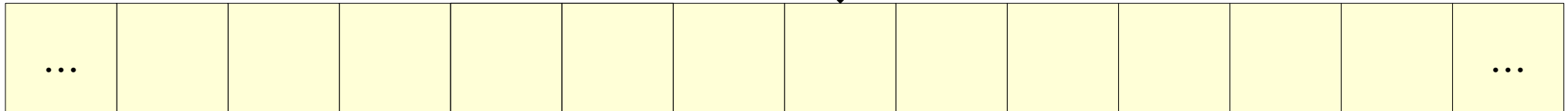
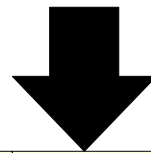
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If Blank Return True  
If 'b' Return False  
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ZipRight:

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If Not Blank Goto ZipRight  
Move Left  
If Not 'b' Return False  
Write Blank
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ZipLeft:

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Move Left  
If Not Blank Goto ZipLeft  
Move Right  
Goto Start
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Start:

If Blank Return True

If 'b' Return False

Write Blank

ZipRight:

Move Right

If Not Blank Goto ZipRight

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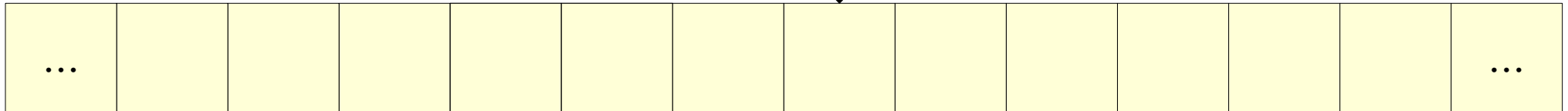
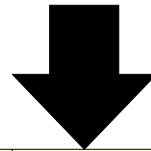
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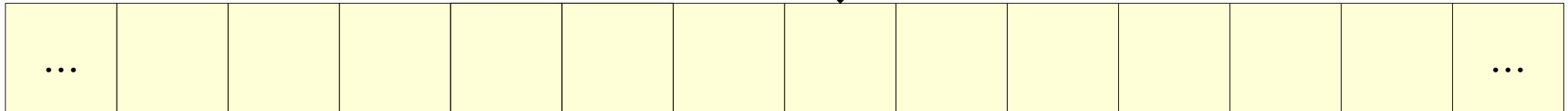
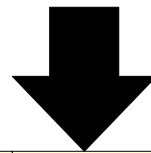
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Time-Out for Announcements!

Second Midterm Logistics

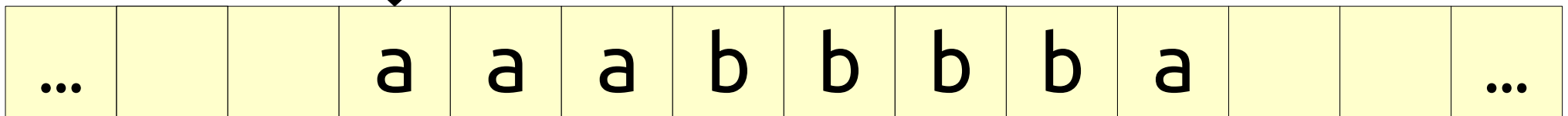
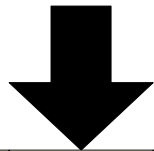
- Our second midterm exam is ***Tuesday, May 20th*** from ***6-9 PM***.
- Topic coverage is primarily lectures 06 – 15 (functions through DFAs & NFAs) and PS3 – PS5 and the first two questions of PS6.
 - Because the material is cumulative, topics from PS1 – PS2 and Lectures 00 – 05 are also fair game.
- The exam is closed-book and closed-computer. You can bring one double-sided 8.5" × 11" sheet of notes with you.
- Seating assignments will be posted ... soon.
- Students with OAE accommodations: Exam locations have been emailed.

Back to CS103!

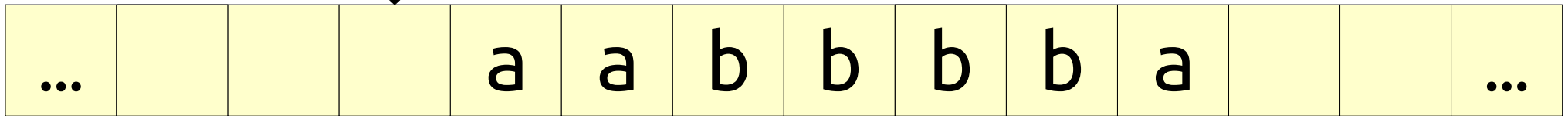
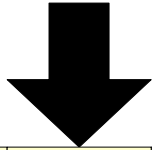
Our Next Challenge

- Let's try a more involved language:
$$\{ w \in \{\mathbf{a}, \mathbf{b}\}^* \mid w \text{ has an equal number of } \mathbf{a}\text{'s and } \mathbf{b}\text{'s} \}$$
- This language is not regular (do you see why?)
- It is context-free, but it's a bit tricky to write a CFG for it.
- Let's see how to design a TM for it.

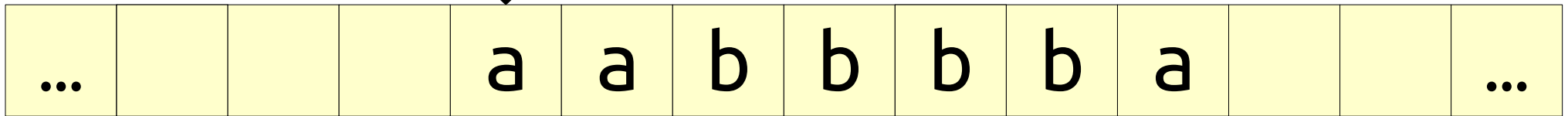
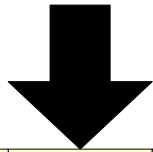
A Caveat



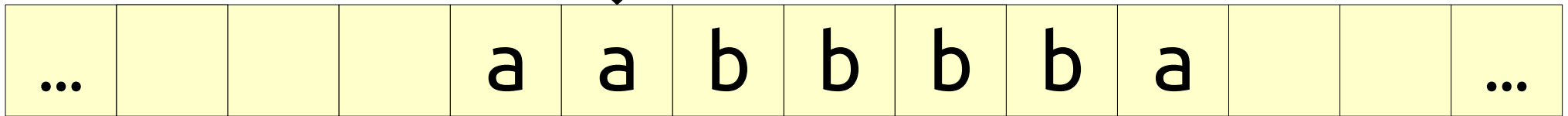
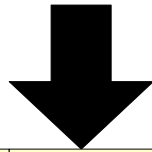
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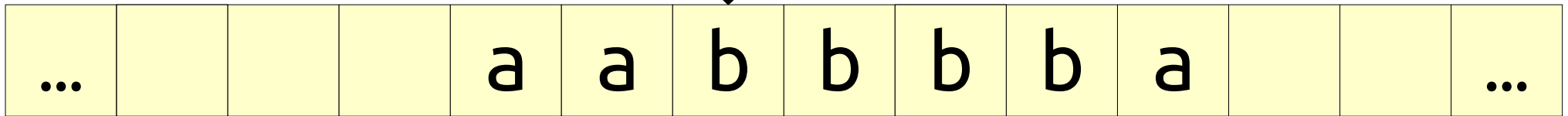
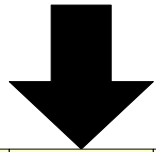
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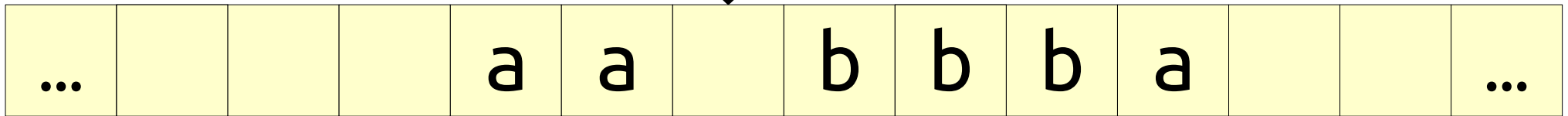
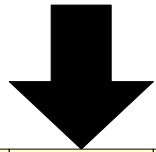
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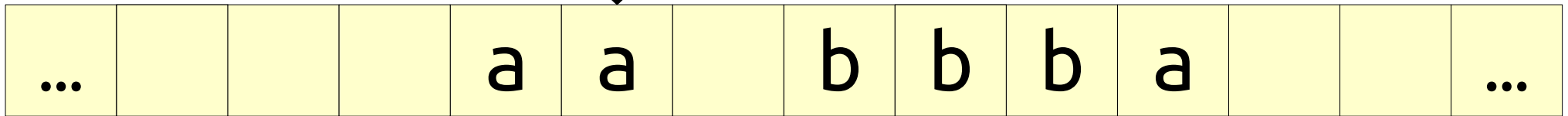
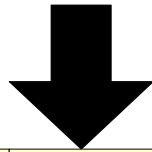
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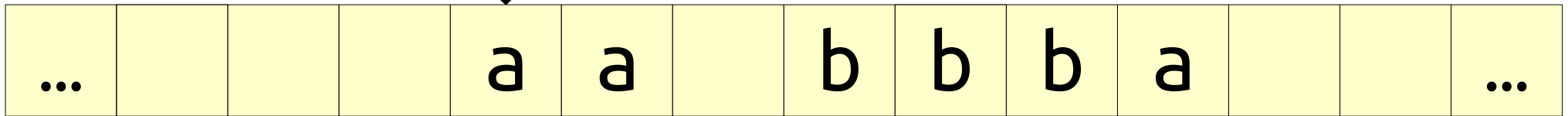
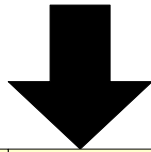
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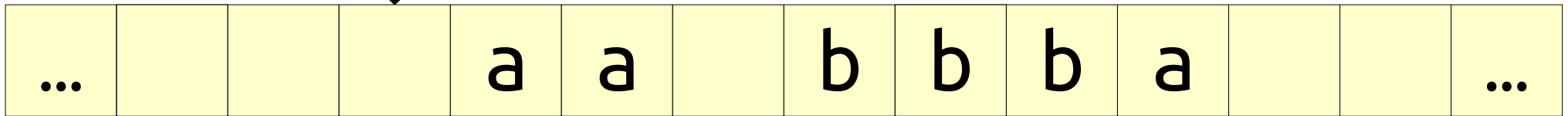
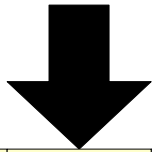
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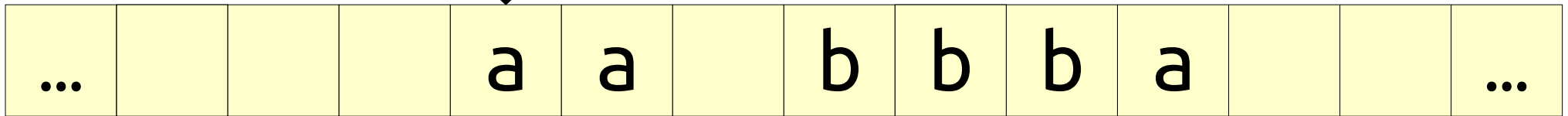
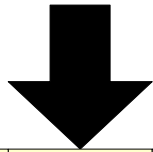
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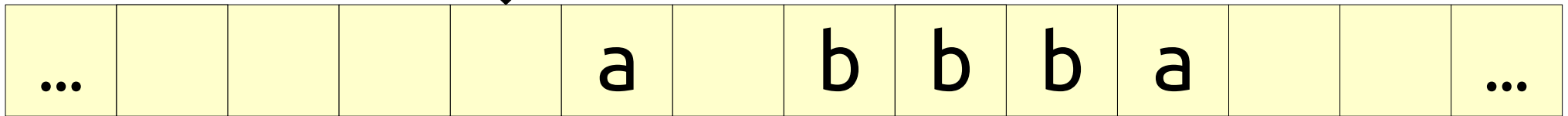
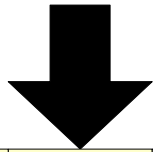
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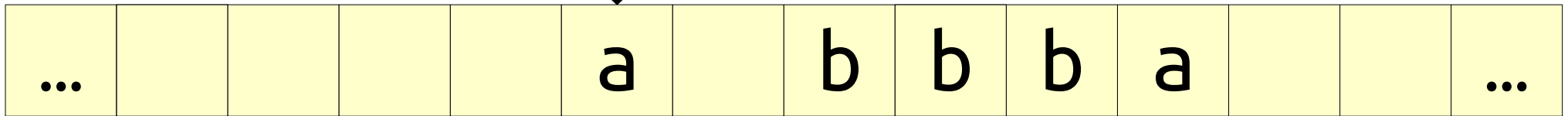
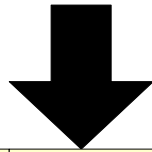
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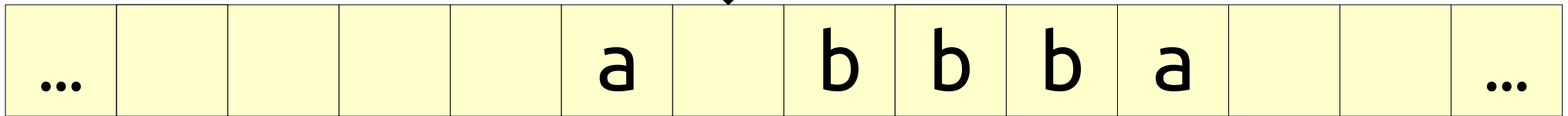
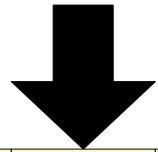
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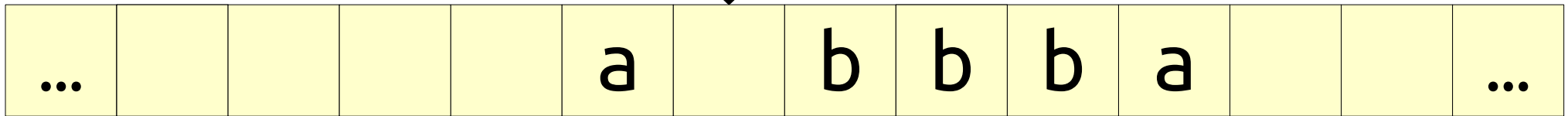
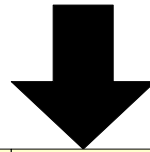
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A Caveat

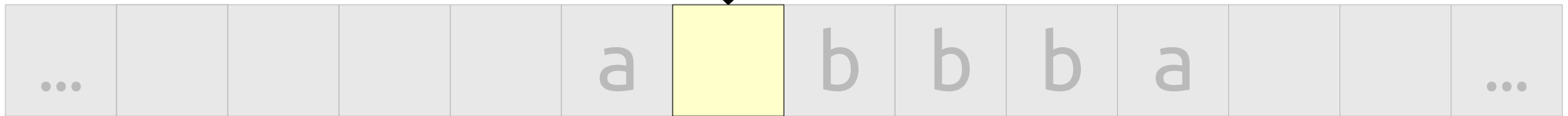
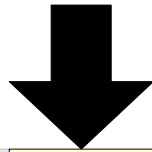


A Caveat



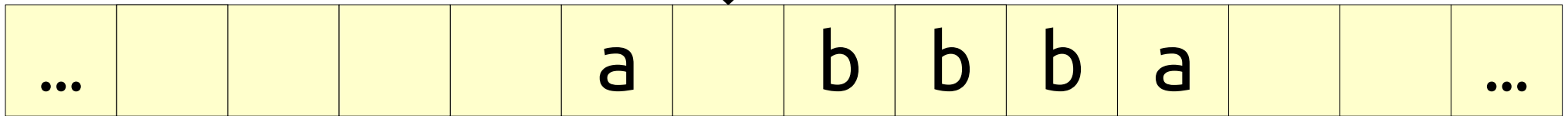
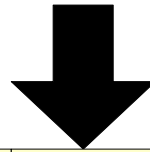
How do we know that
this blank isn't one of
the infinitely many
blanks after our input
string?

A Caveat



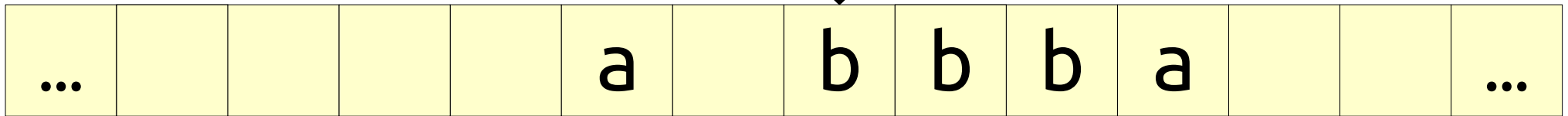
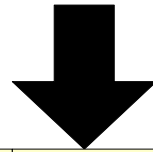
How do we know that
this blank isn't one of
the infinitely many
blanks after our input
string?

A Caveat

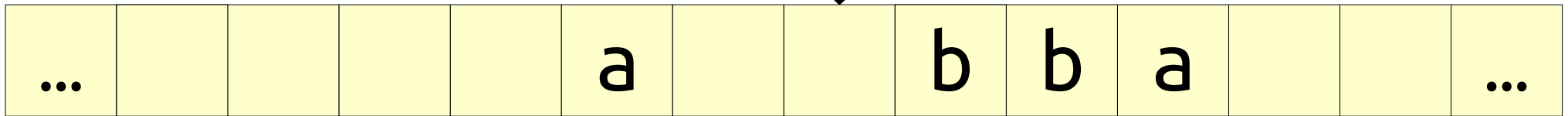
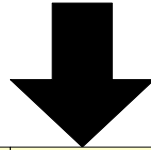


How do we know that
this blank isn't one of
the infinitely many
blanks after our input
string?

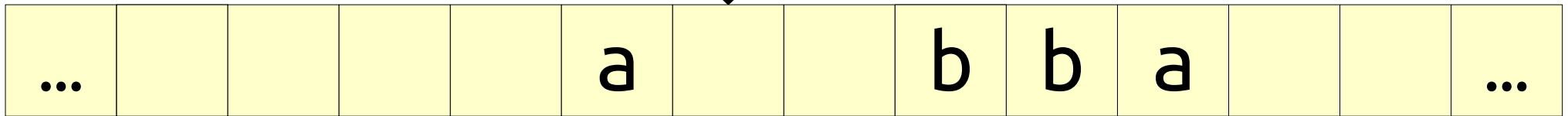
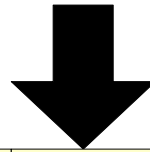
A Caveat



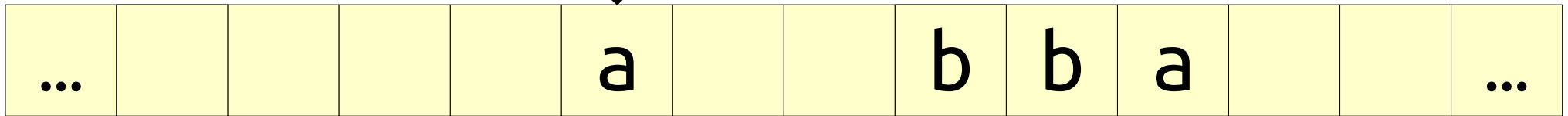
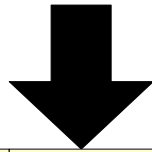
A Caveat



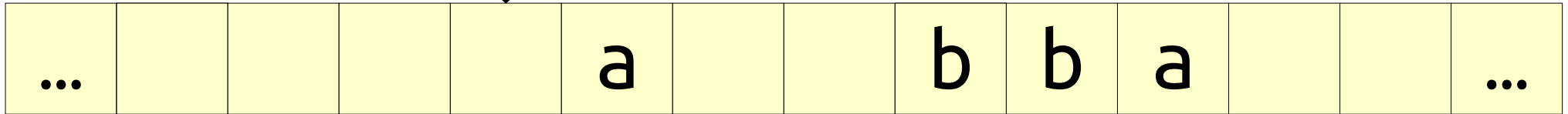
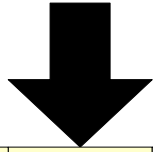
A Caveat



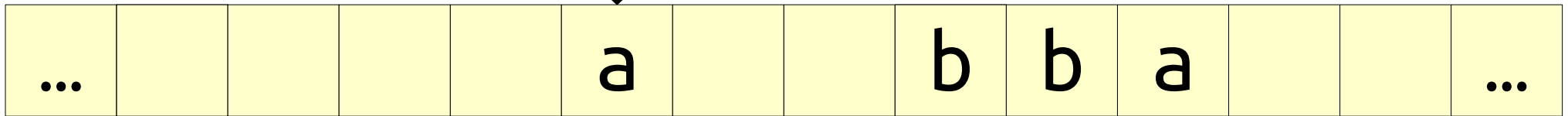
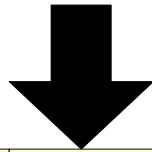
A Caveat



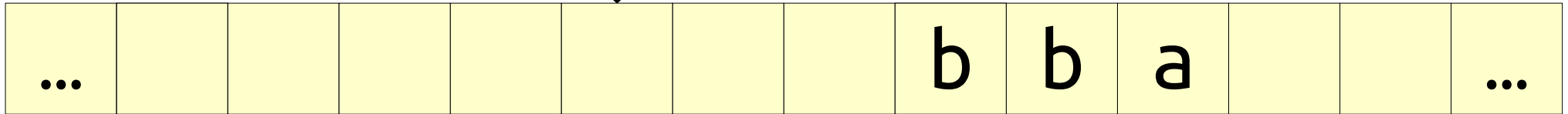
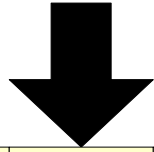
A Caveat



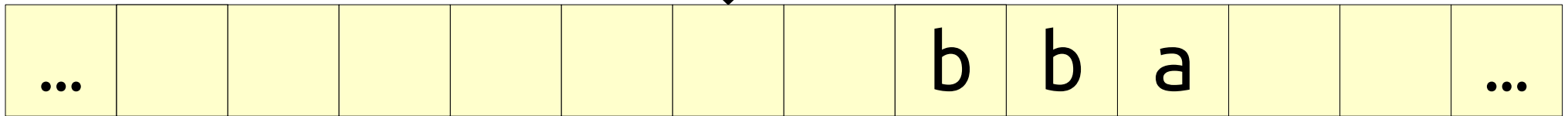
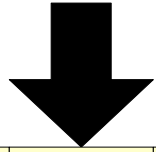
A Caveat



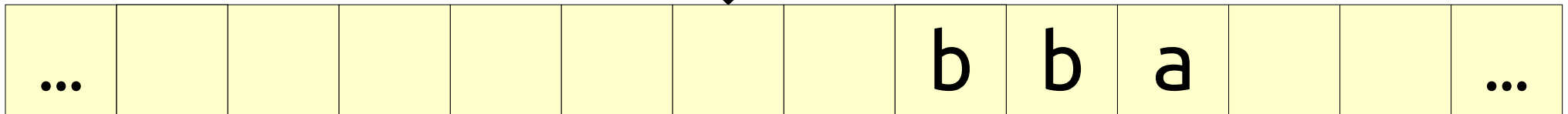
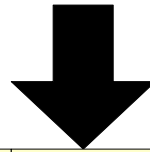
A Caveat



A Caveat

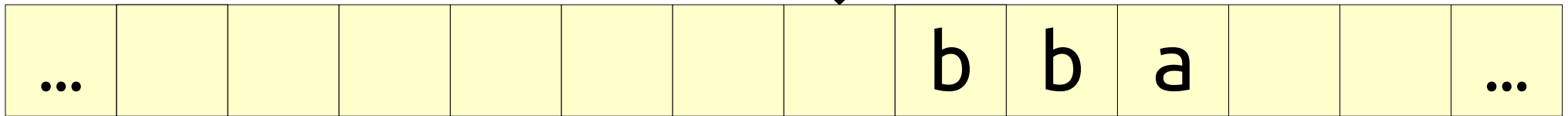
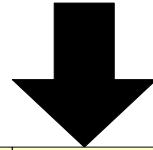


A Caveat

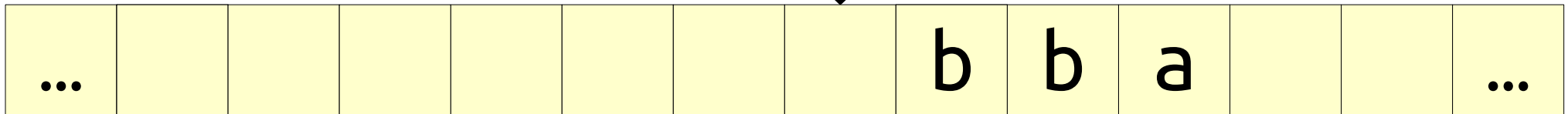
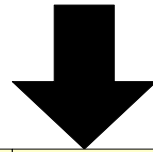


How do we know that
this blank isn't one of
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A Caveat

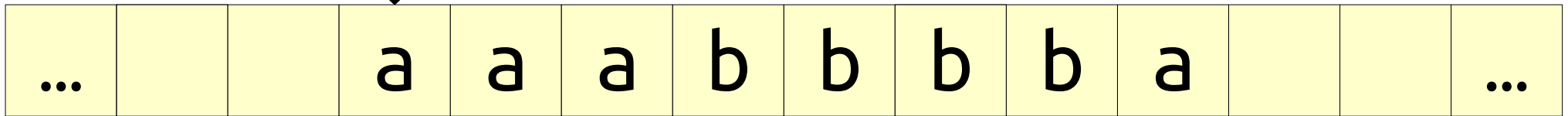
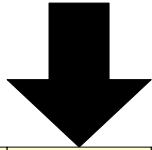


A Caveat

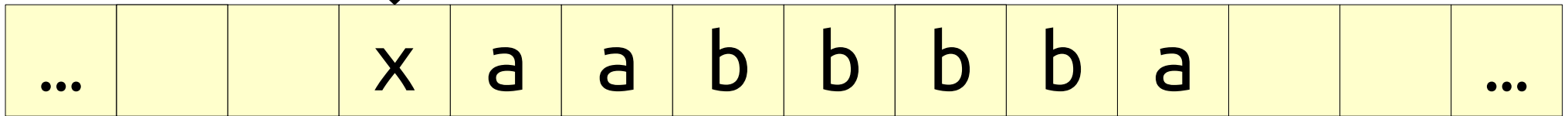
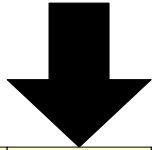


How do we know that
this blank isn't one of
the infinitely many
blanks after our input
string?

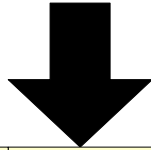
One Solution



One Solution

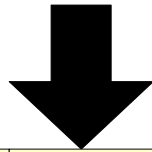


One Solution



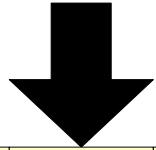
...			x	a	a	b	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution



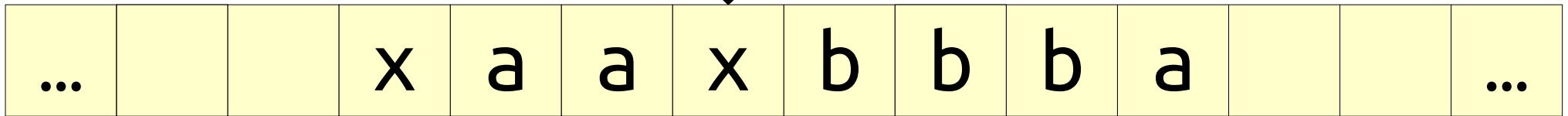
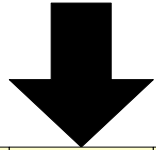
...			x	a	a	b	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution

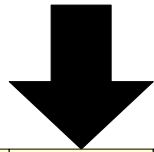


...			x	a	a	b	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution

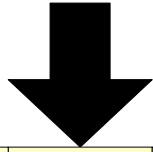


One Solution



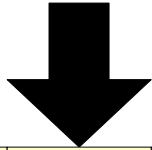
...			x	a	a	x	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution



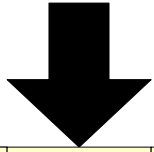
...			x	a	a	x	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution



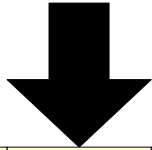
...			x	a	a	x	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution



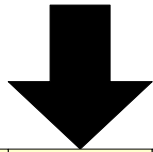
...			x	a	a	x	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution



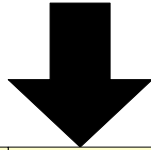
...			x	a	a	x	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution



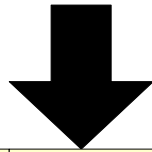
...			x	a	a	x	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution



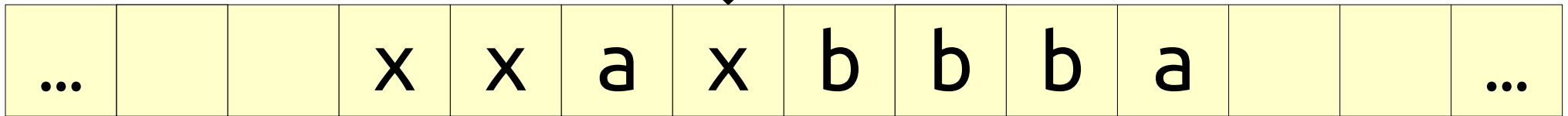
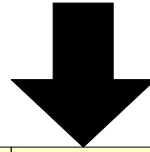
...			x	x	a	x	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution

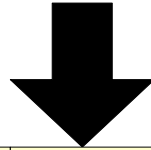


...			x	x	a	x	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution

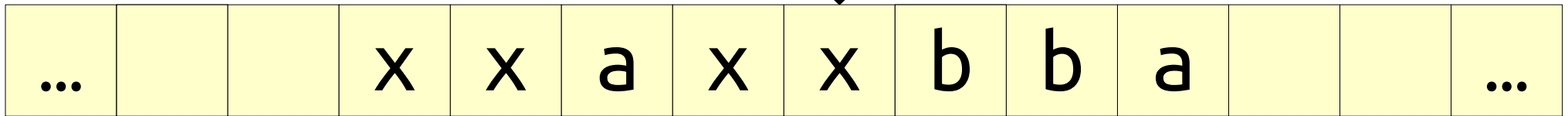
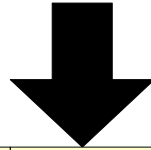


One Solution

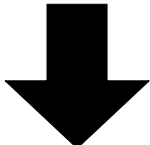


...			x	x	a	x	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

One Solution

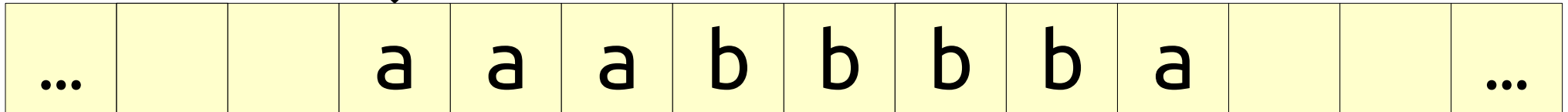
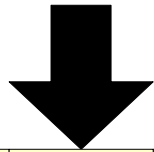


Start:

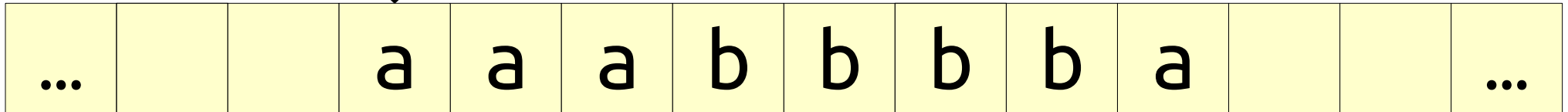
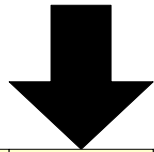


...			a	a	a	b	b	b	b	a			...
-----	--	--	---	---	---	---	---	---	---	---	--	--	-----

Start:

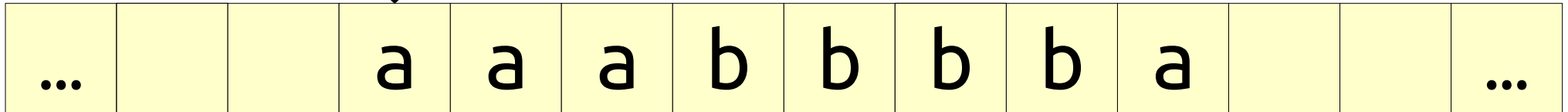
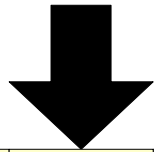


Start:



Start:

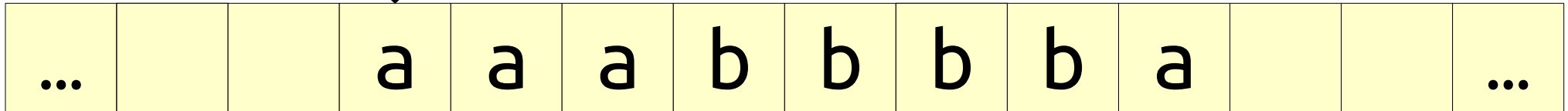
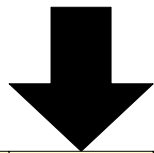
If 'a' Goto FoundA



Start:

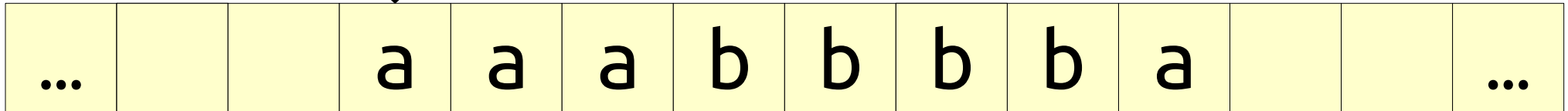
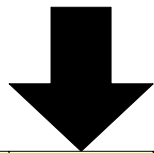
If 'a' Goto FoundA

FoundA:



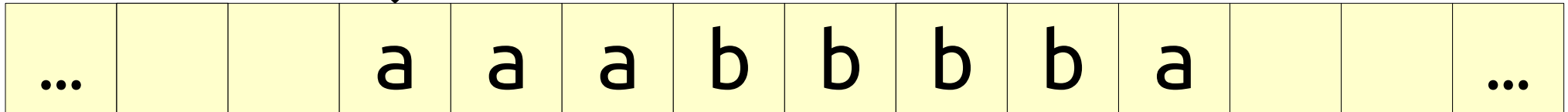
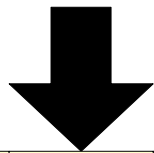
Start:
If 'a' Goto FoundA

FoundA:



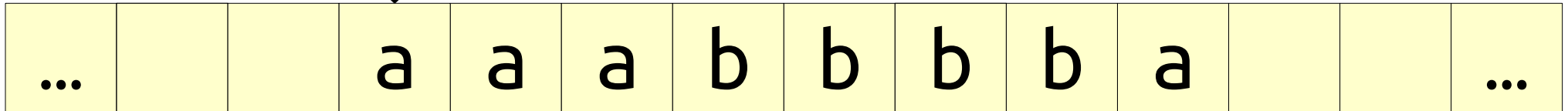
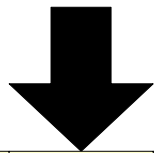
Start:
If 'a' Goto FoundA

FoundA:



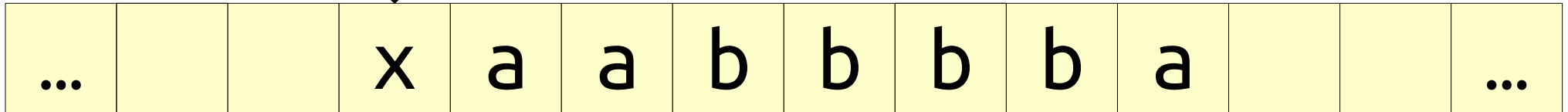
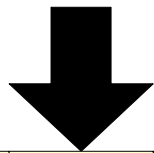
Start:
If 'a' Goto FoundA

FoundA:
Write 'x'



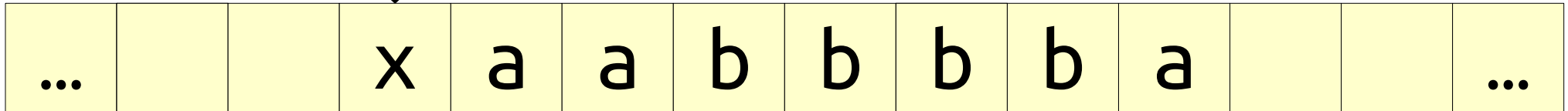
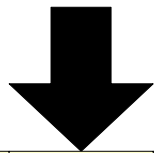
Start:
If 'a' Goto FoundA

FoundA:
Write 'x'



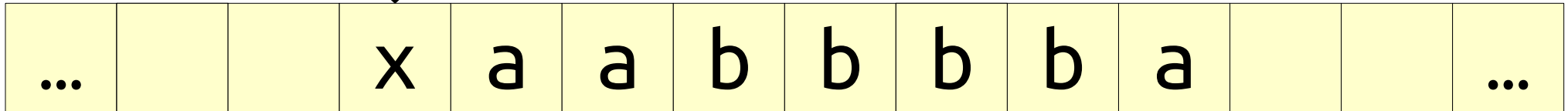
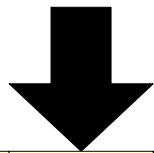
```
Start:  
  If 'a' Goto FoundA
```

```
FoundA:  
  Write 'x'
```



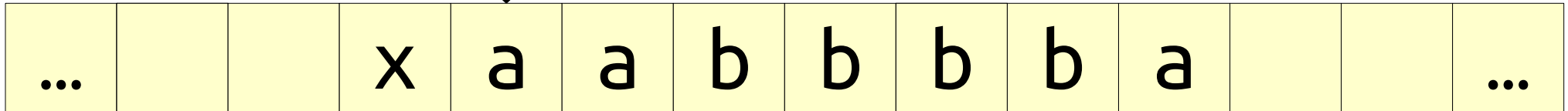
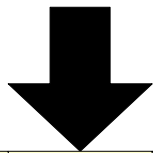
Start:
If 'a' Goto FoundA

FoundA:
Write 'x'
Move Right



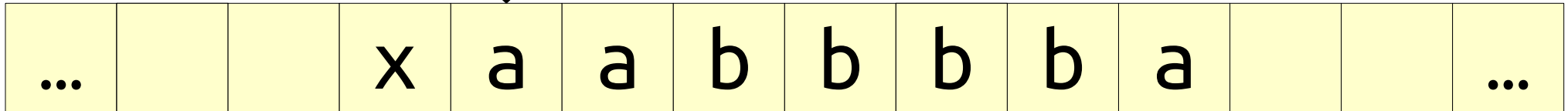
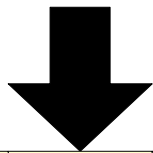
Start:
If 'a' Goto FoundA

FoundA:
Write 'x'
Move Right



```
Start:  
  If 'a' Goto FoundA
```

```
FoundA:  
  Write 'x'  
  Move Right  
  If 'a' ?
```

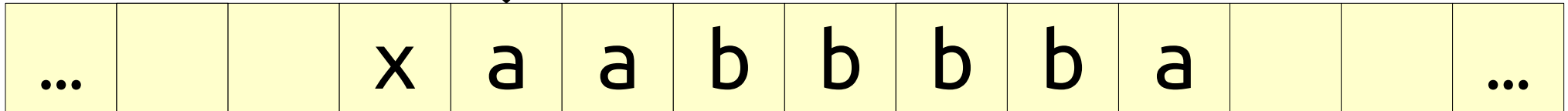
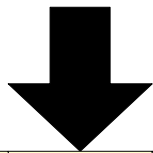


```
Start:  
  If 'a' Goto FoundA
```

```
FoundA:  
  Write 'x'
```

```
  Move Right
```

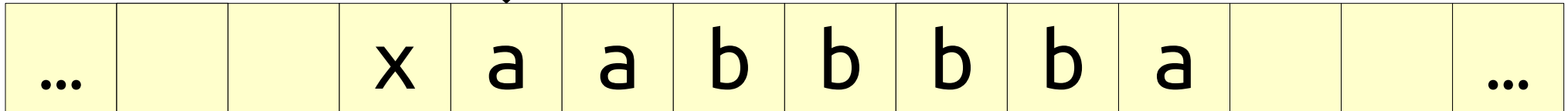
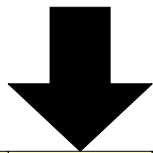
```
  If 'a' ?
```



```
Start:  
  If 'a' Goto FoundA
```

```
FoundA:  
  Write 'x'
```

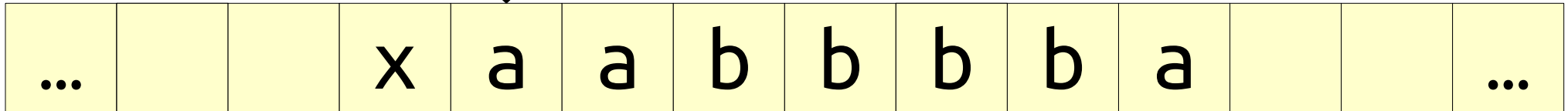
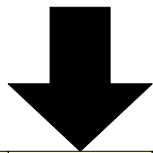
```
LoopA:  
  Move Right  
  If 'a' ?
```



```
Start:  
  If 'a' Goto FoundA
```

```
FoundA:  
  Write 'x'
```

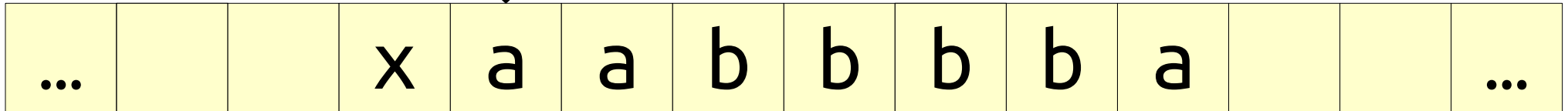
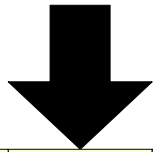
```
LoopA:  
  Move Right  
  If 'a' Goto LoopA
```



```
Start:  
  If 'a' Goto FoundA
```

```
FoundA:  
  Write 'x'
```

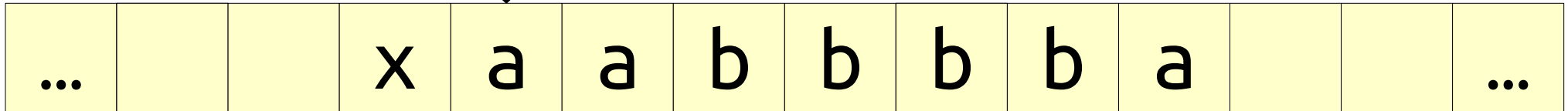
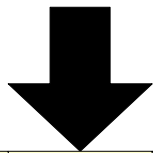
```
LoopA:  
  Move Right  
  If 'a' Goto LoopA
```



```
Start:  
  If 'a' Goto FoundA
```

```
FoundA:  
  Write 'x'
```

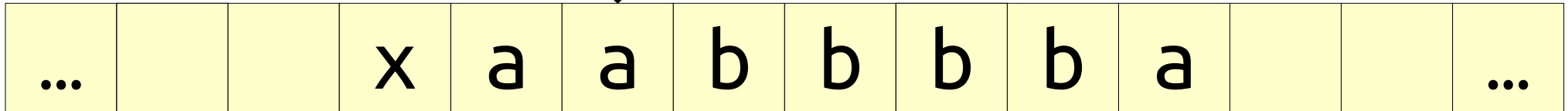
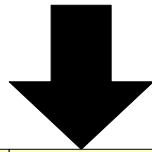
```
LoopA:  
  Move Right  
  If 'a' Goto LoopA
```



```
Start:  
  If 'a' Goto FoundA
```

```
FoundA:  
  Write 'x'
```

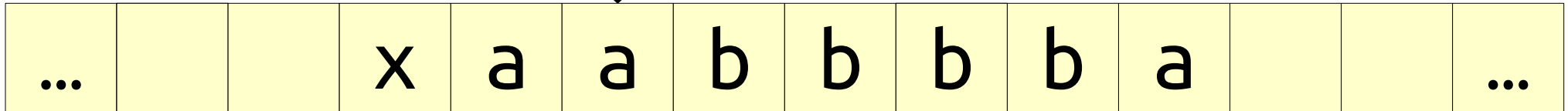
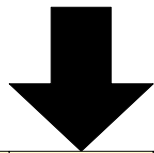
```
LoopA:  
  Move Right  
  If 'a' Goto LoopA
```



```
Start:  
  If 'a' Goto FoundA
```

```
FoundA:  
  Write 'x'
```

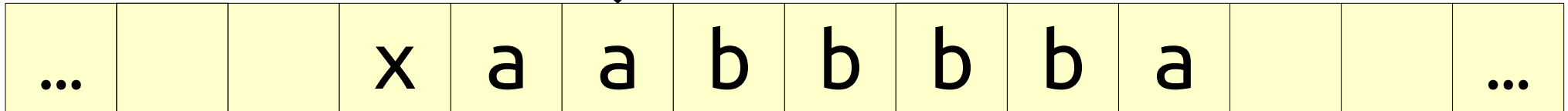
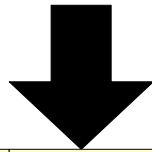
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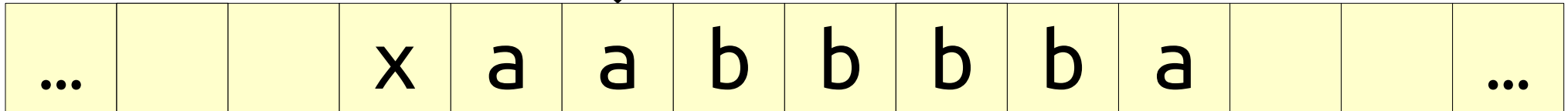
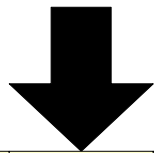
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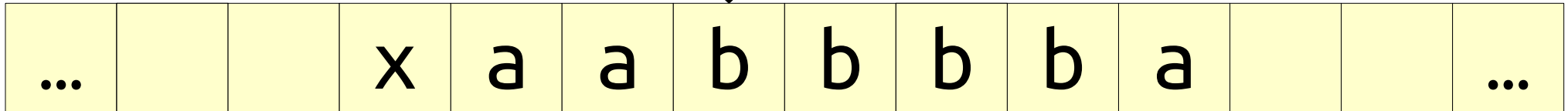
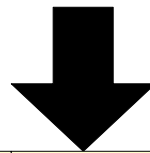
```
LoopA:  
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```



```
Start:  
  If 'a' Goto FoundA
```

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```

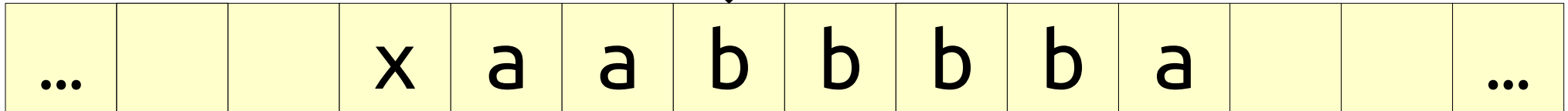
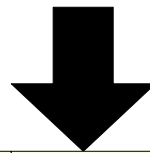
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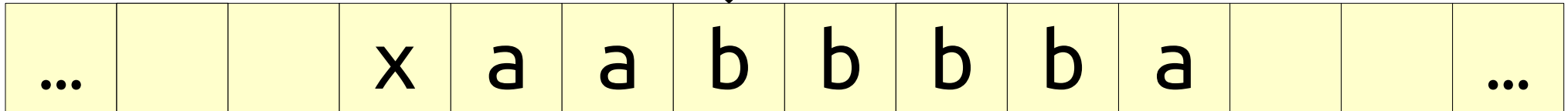
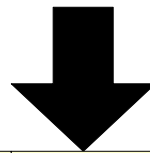
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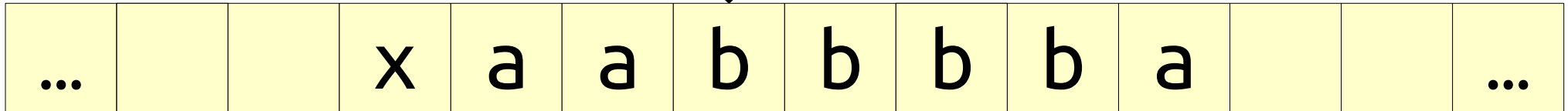
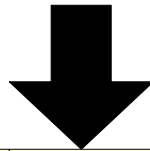
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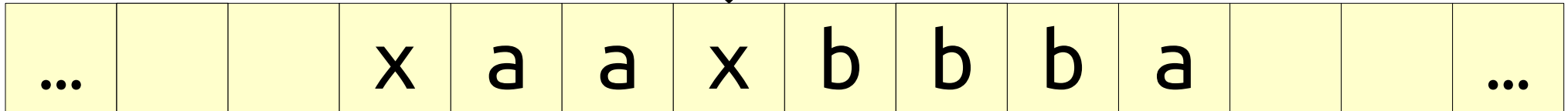
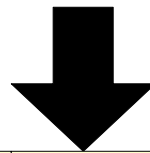
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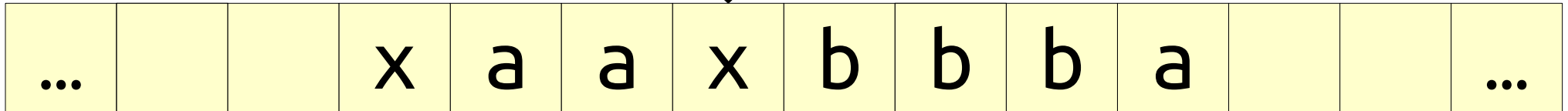
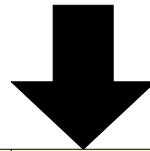
```
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  If 'a' Goto LoopA  
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Start:  
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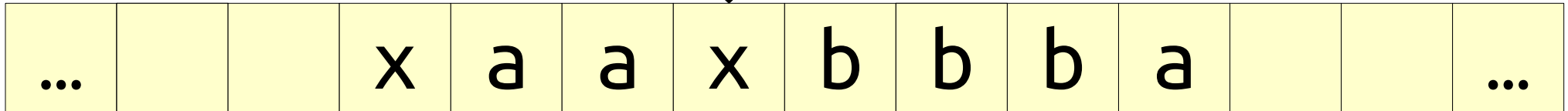
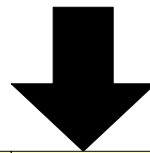
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  If 'a' Goto FoundA
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FoundA:  
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```
LoopA:  
  Move Right  
  If 'a' Goto LoopA  
  Write 'x'  
  Goto GoHome
```

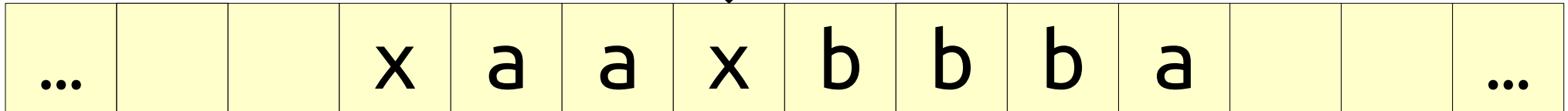
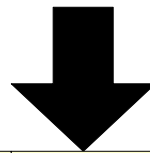


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  If 'a' Goto FoundA
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LoopA:  
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```

```
GoHome:  
  Move Left  
  If Not Blank Goto GoHome  
  Move Right  
  Goto Start
```



Start:

If 'a' Goto FoundA

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

Write 'x'

Goto GoHome

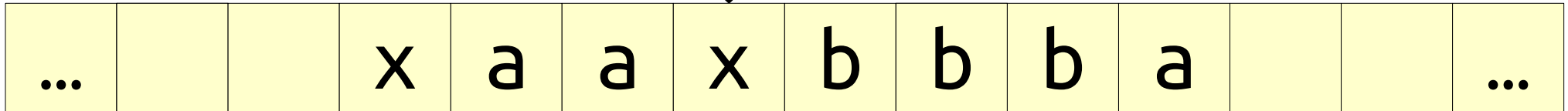
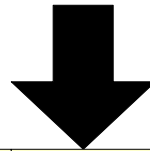
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

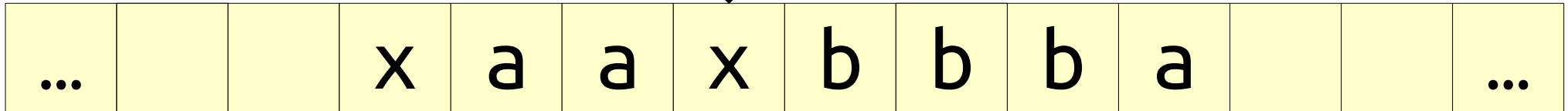
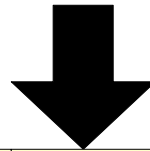


Start:
 If 'a' Goto FoundA

FoundA:
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LoopA:
 Move Right
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 Write 'x'
 Goto GoHome

GoHome:
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 Goto Start

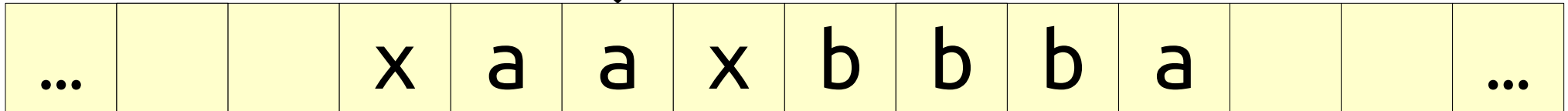
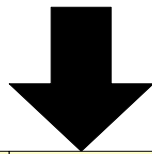


Start:
 If 'a' Goto FoundA

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 Move Right
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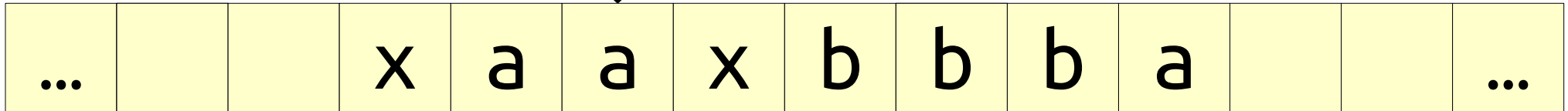
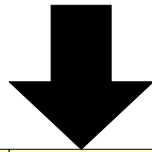


```
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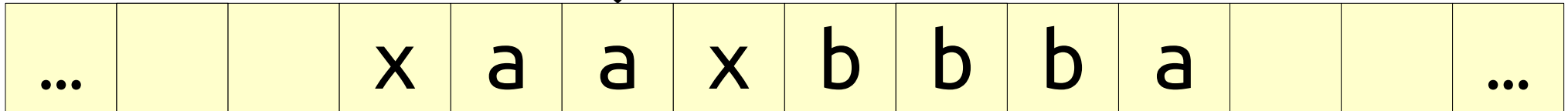
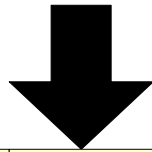
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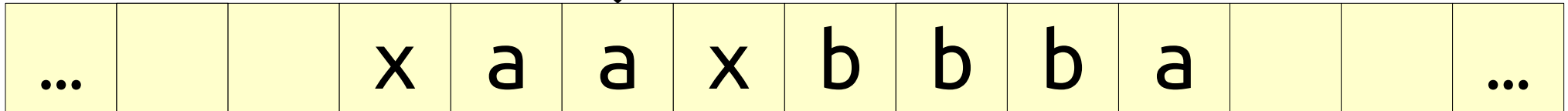
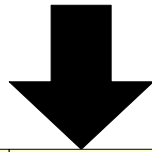


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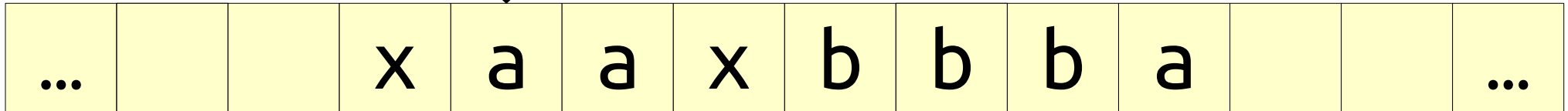
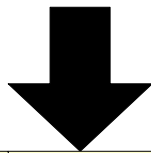


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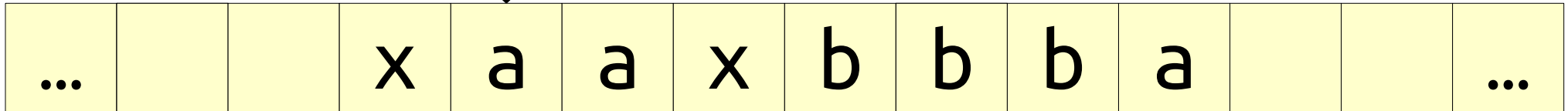
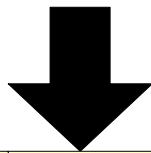


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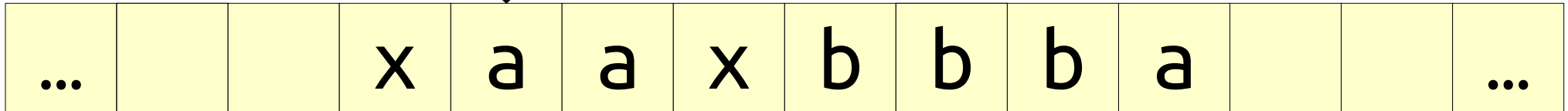
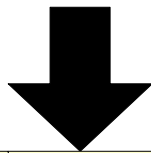
GoHome:

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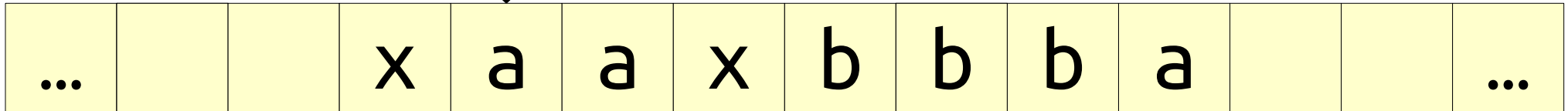
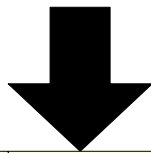


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Start:
If 'a' Goto FoundA

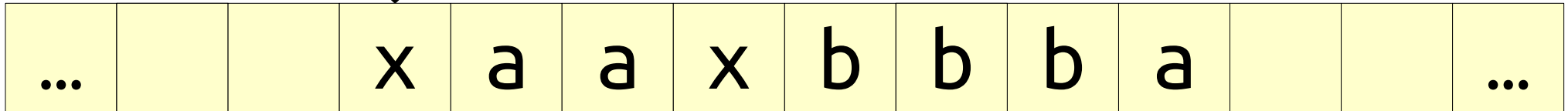
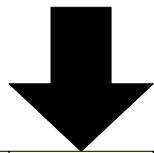
FoundA:
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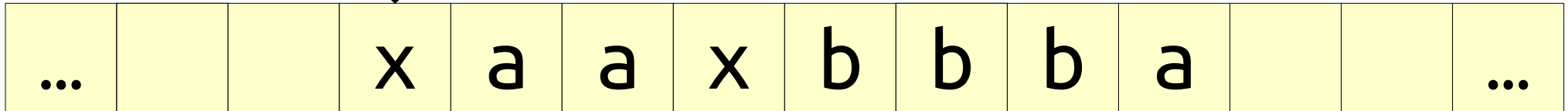
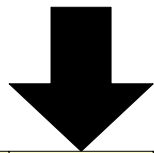


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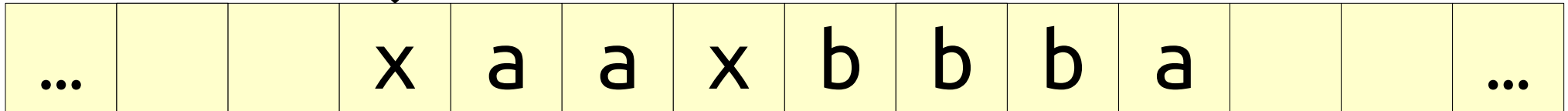
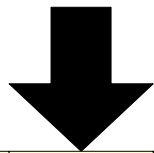
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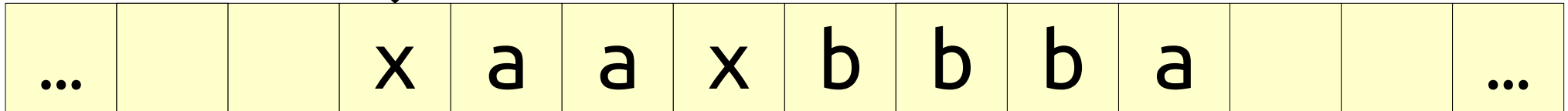
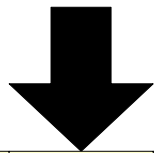


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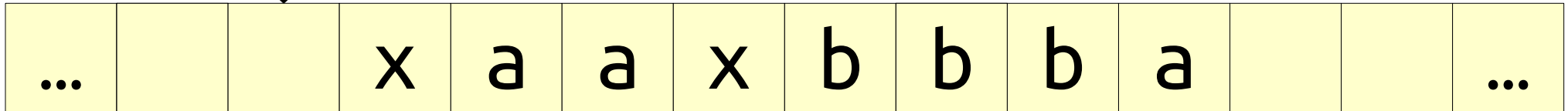
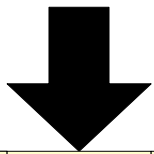


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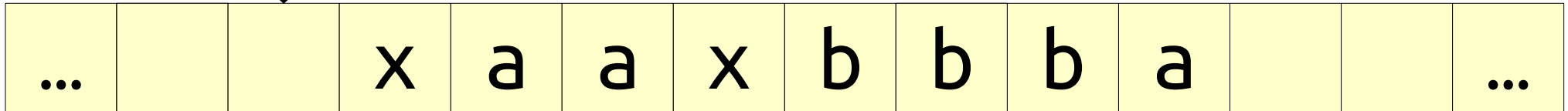
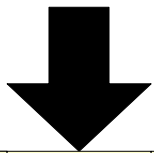


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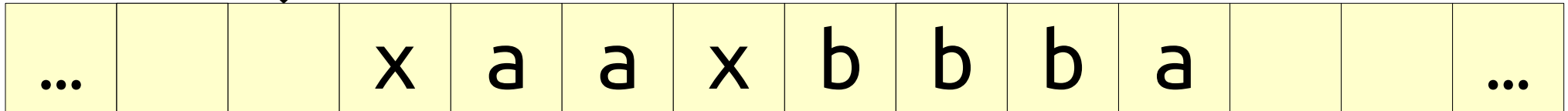
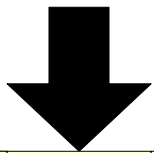


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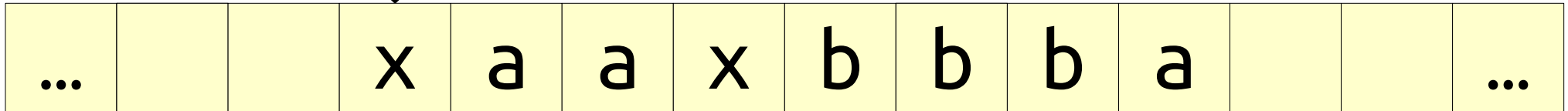
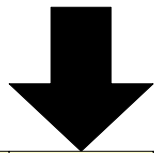


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  Goto Start
```

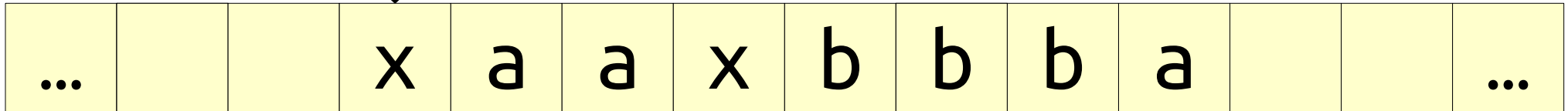
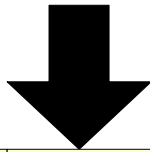


```
Start:  
  If 'a' Goto FoundA
```

```
FoundA:  
  Write 'x'
```

```
LoopA:  
  Move Right  
  If 'a' Goto LoopA  
  Write 'x'  
  Goto GoHome
```

```
GoHome:  
  Move Left  
  If Not Blank Goto GoHome  
  Move Right  
  Goto Start
```



Start:

If 'a' Goto FoundA

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

Write 'x'

Goto GoHome

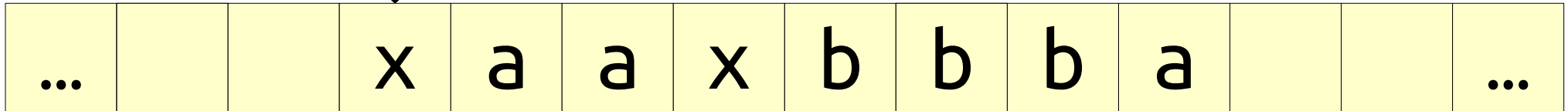
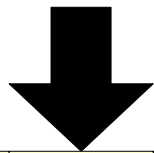
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

Write 'x'

Goto GoHome

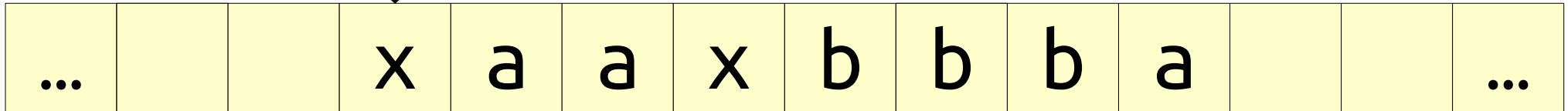
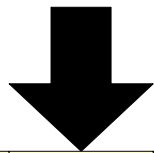
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

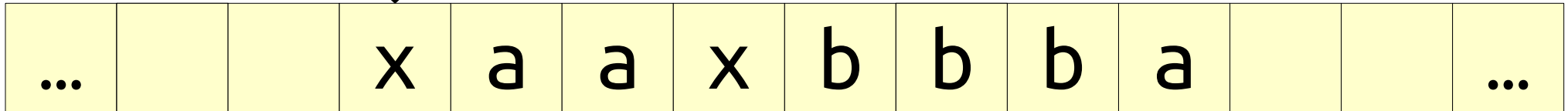
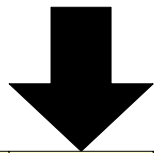


Start:
If 'a' Goto FoundA

FoundA:
Write 'x'

LoopA:
Move Right
If 'a' Goto LoopA
Write 'x'
Goto GoHome

GoHome:
Move Left
If Not Blank Goto GoHome
Move Right
Goto Start



Start:

If 'a' Goto FoundA

Move Right

FoundA:

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LoopA:

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If 'a' Goto LoopA

Write 'x'

Goto GoHome

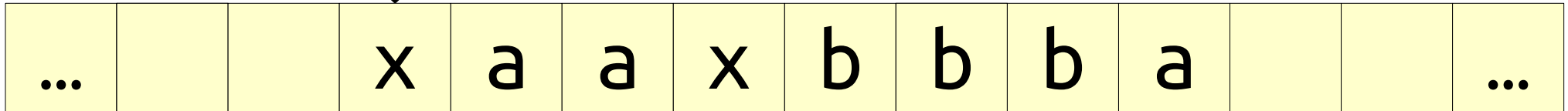
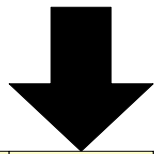
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



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If 'a' Goto FoundA

Move Right

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LoopA:

Move Right

If 'a' Goto LoopA

Write 'x'

Goto GoHome

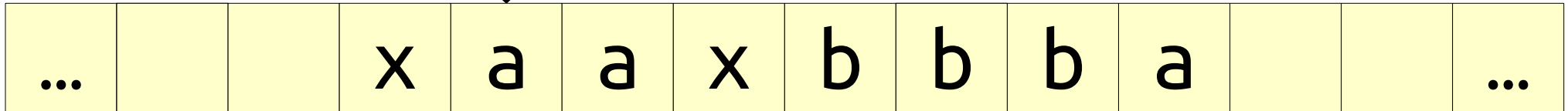
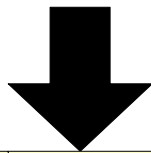
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA
Move Right

GoHome:

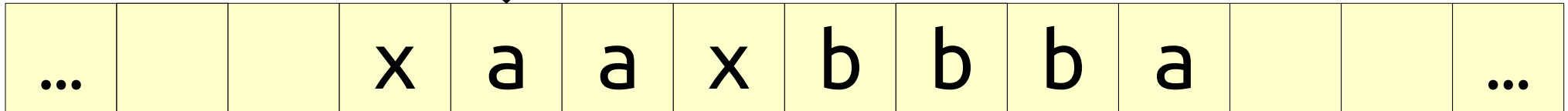
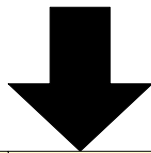
Move Left
If Not Blank Goto GoHome
Move Right
Goto Start

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If 'a' Goto LoopA
Write 'x'
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If 'a' Goto LoopA

Write 'x'

Goto GoHome

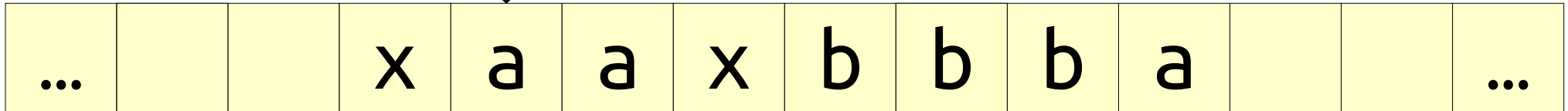
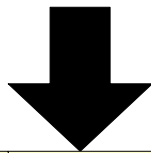
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

```
If 'a' Goto FoundA  
Move Right  
Goto Start
```

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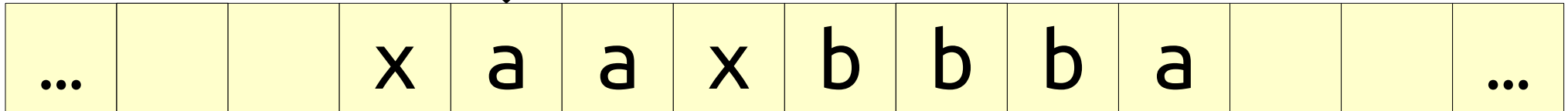
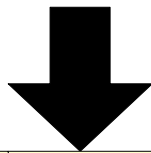
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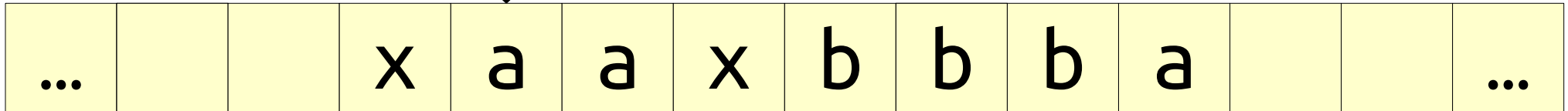
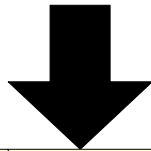
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

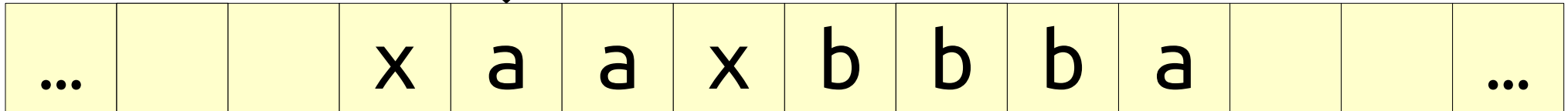
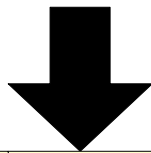


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Start:  
  If 'a' Goto FoundA  
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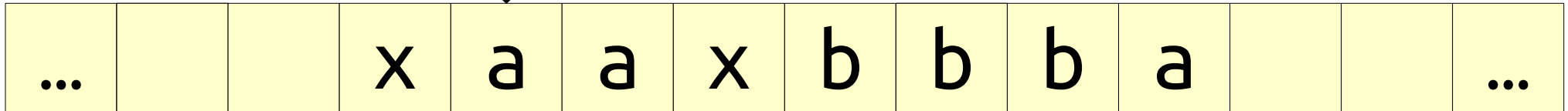
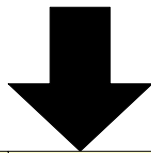
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Start:  
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```

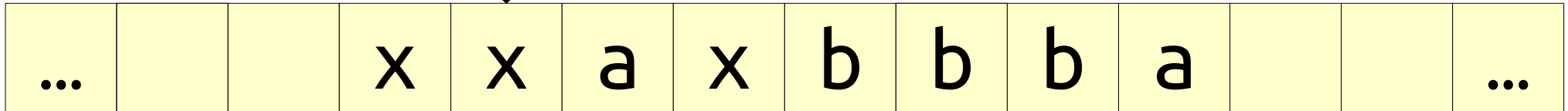
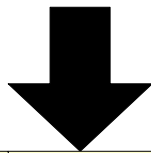
```
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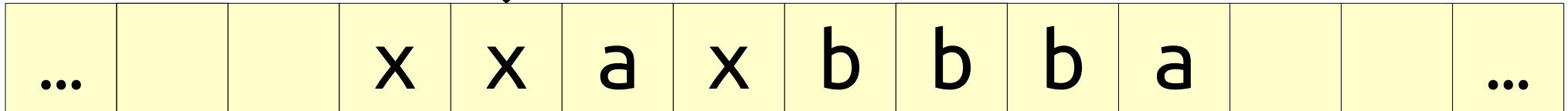
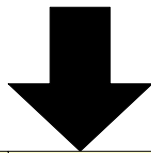


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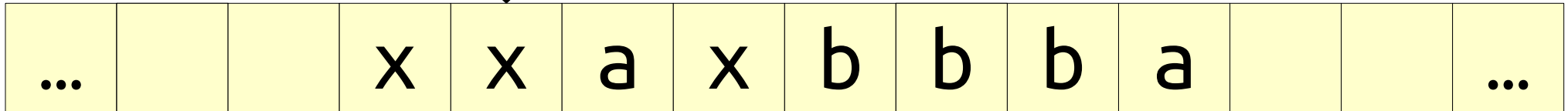
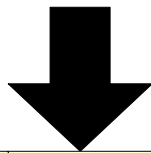
GoHome:

```
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Goto Start
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```

```
Goto GoHome
```

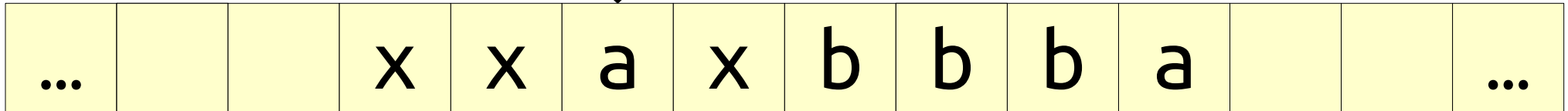
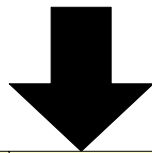
GoHome:

```
Move Left
```

```
If Not Blank Goto GoHome
```

```
Move Right
```

```
Goto Start
```



Start:

```
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Move Right  
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```

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```
Goto GoHome
```

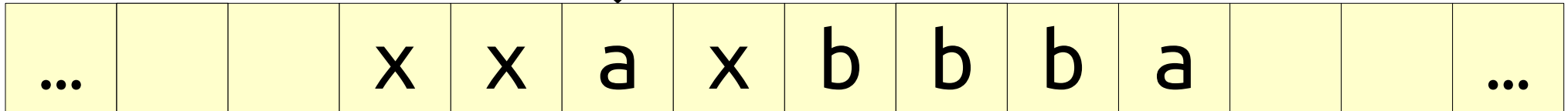
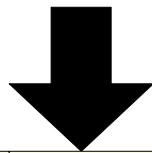
GoHome:

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Goto Start
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FoundA:

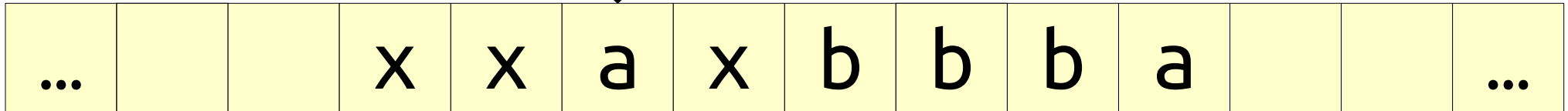
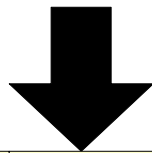
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LoopA:

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GoHome:

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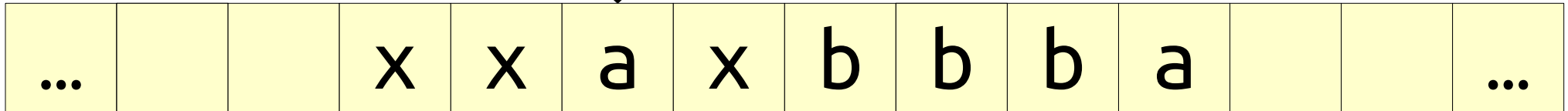
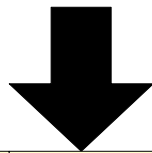
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Move Right
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Write 'x'
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Goto GoHome
```

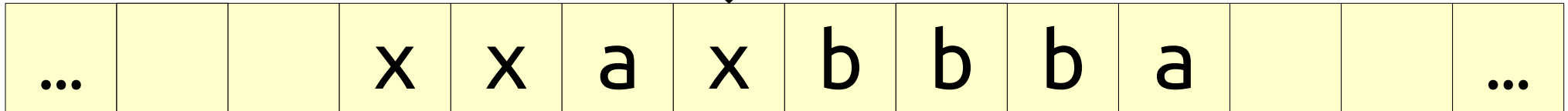
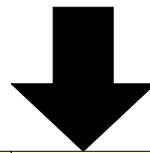
GoHome:

```
Move Left
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Move Right  
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Goto GoHome
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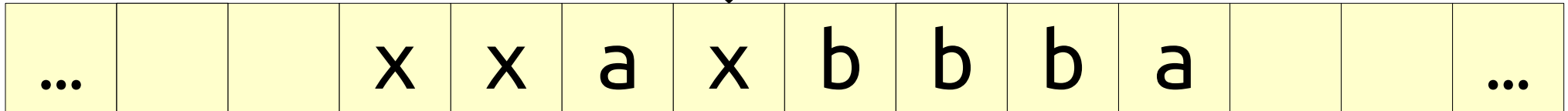
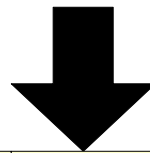
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Move Right
Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

Write 'x'

Goto GoHome

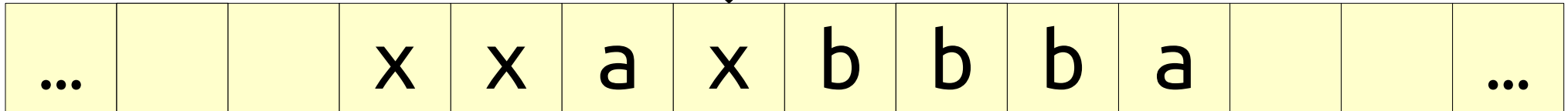
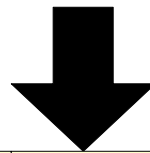
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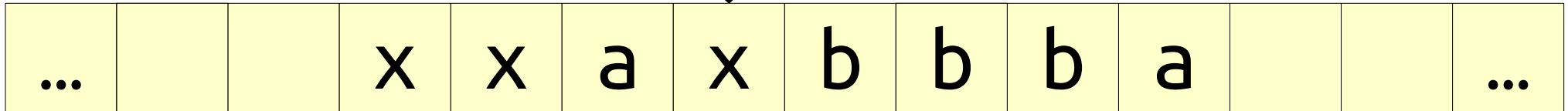
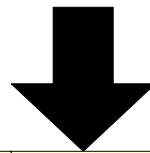
LoopA:

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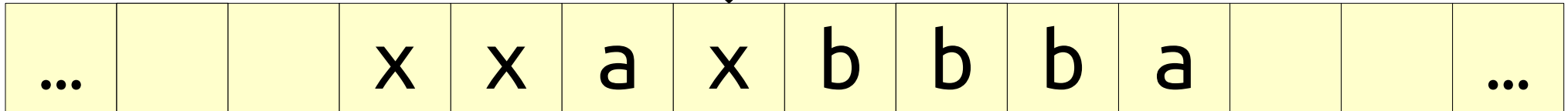
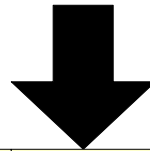
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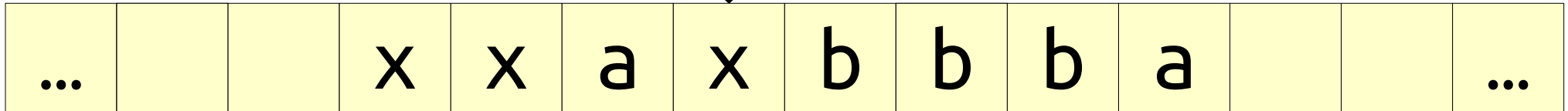
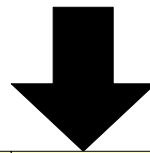
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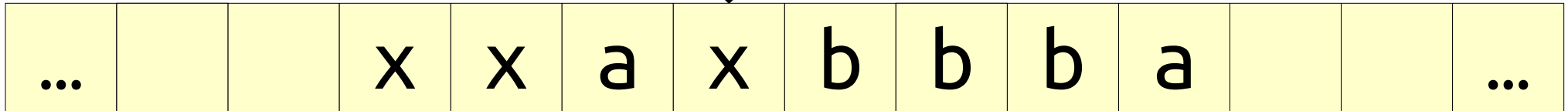
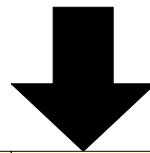
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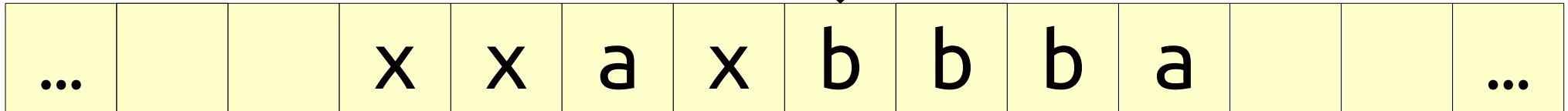
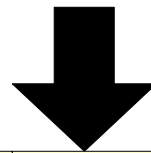


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```

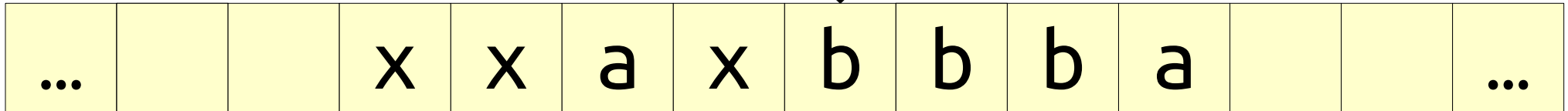
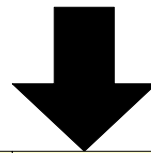
GoHome:

```
Move Left
```

```
If Not Blank Goto GoHome
```

```
Move Right
```

```
Goto Start
```



Start:

```
If 'a' Goto FoundA  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right
```

```
If 'a' Goto LoopA
```

```
If 'x' Goto LoopA
```

```
Write 'x'
```

```
Goto GoHome
```

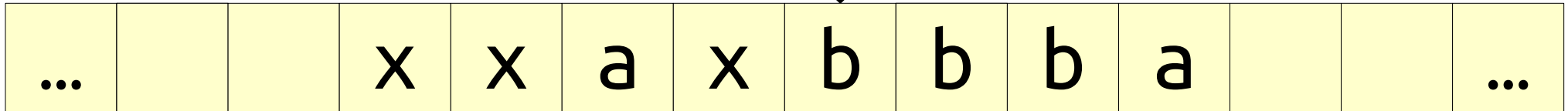
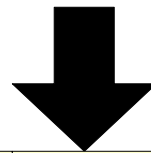
GoHome:

```
Move Left
```

```
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```

```
Move Right
```

```
Goto Start
```

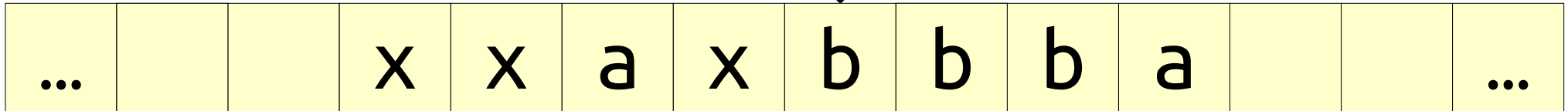
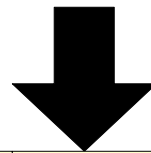


```
Start:  
  If 'a' Goto FoundA  
  Move Right  
  Goto Start
```

```
FoundA:  
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```

```
LoopA:  
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GoHome:  
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  Goto Start
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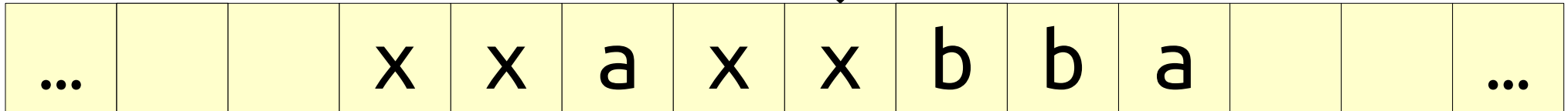
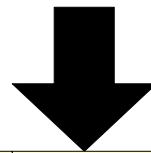


```
Start:  
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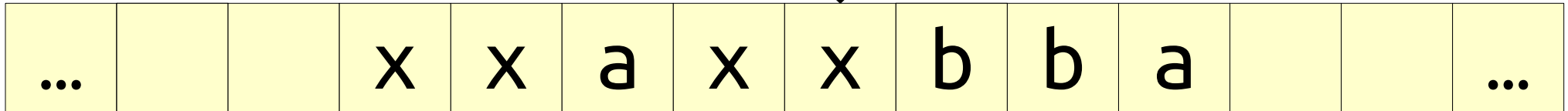
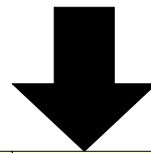


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FoundA:

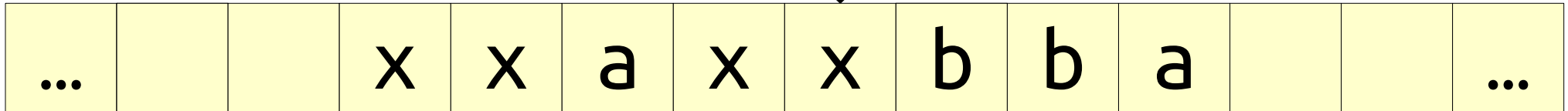
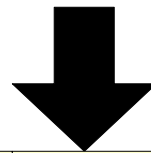
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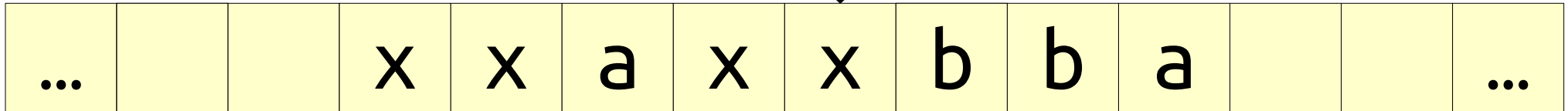
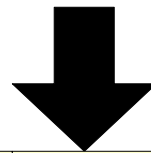
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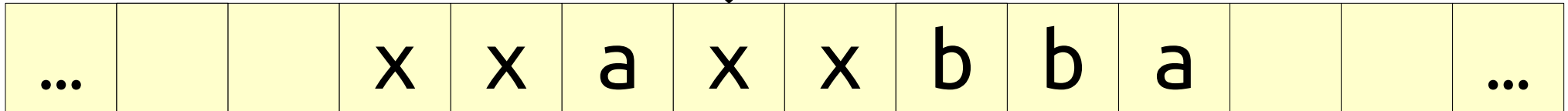
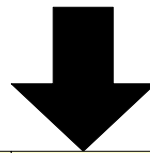
LoopA:

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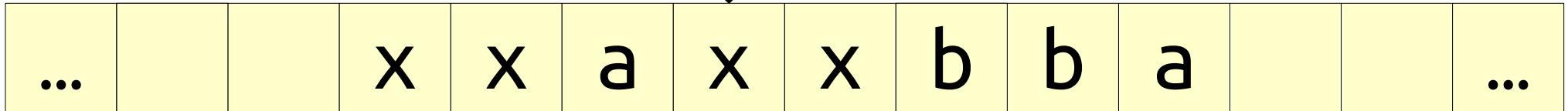
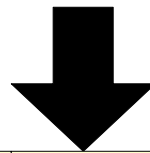


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```

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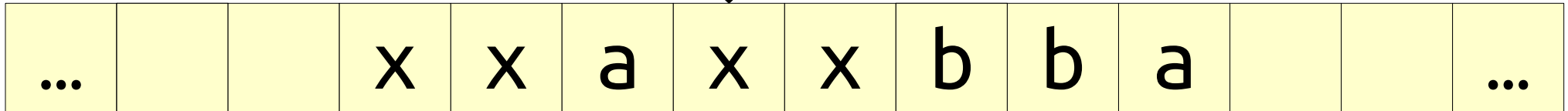
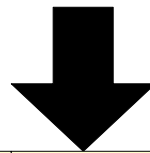
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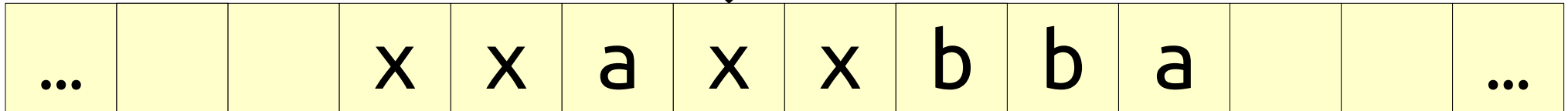
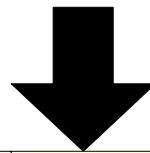
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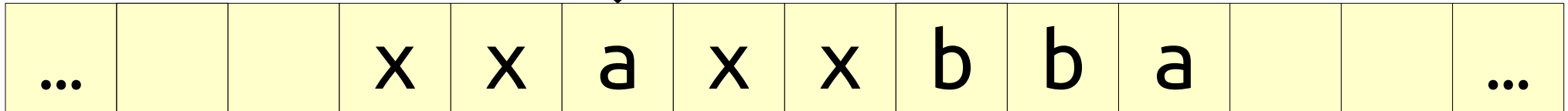
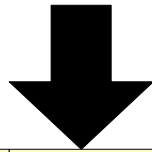
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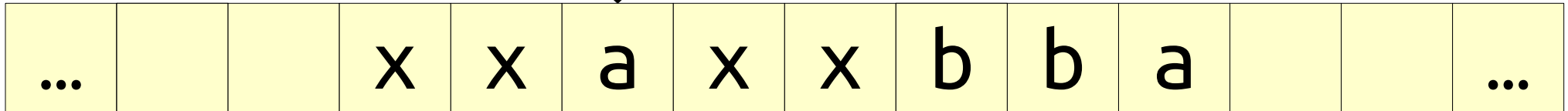
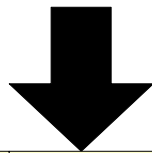


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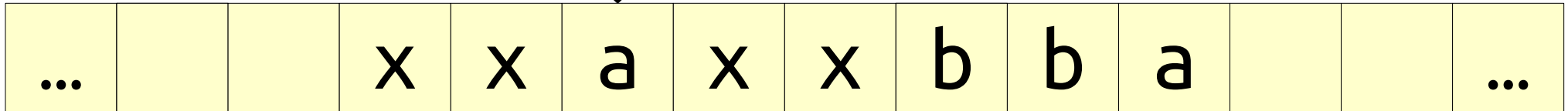
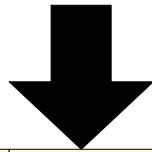
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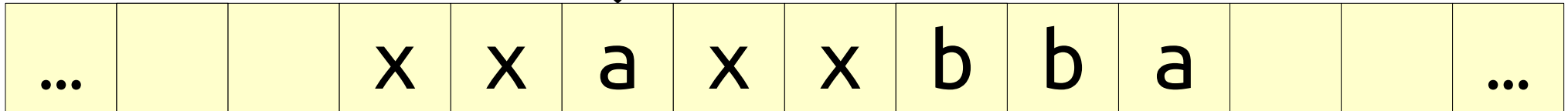
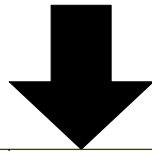
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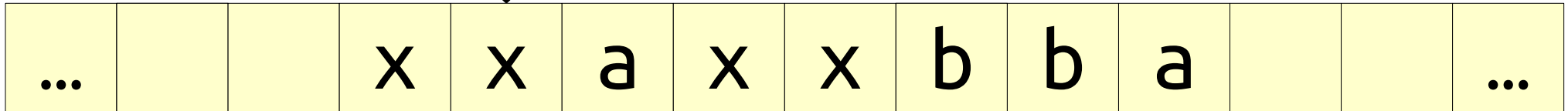
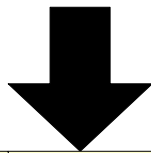
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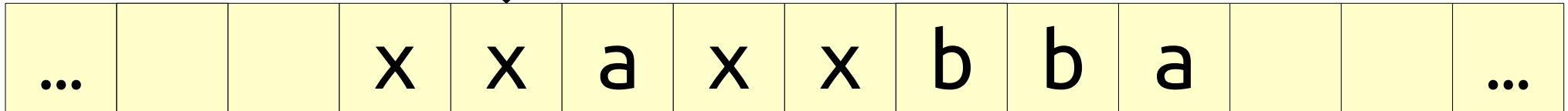
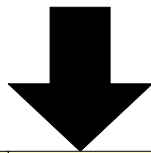


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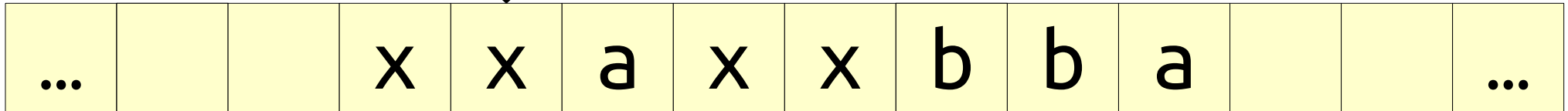
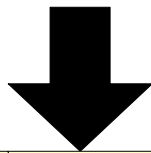
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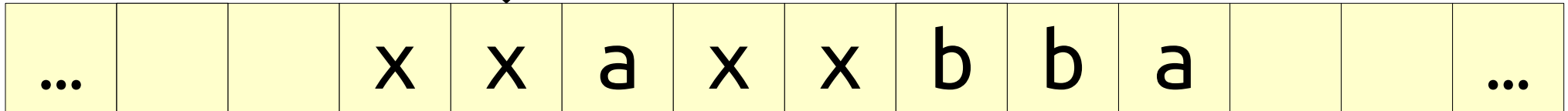
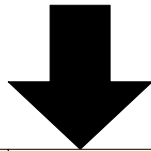
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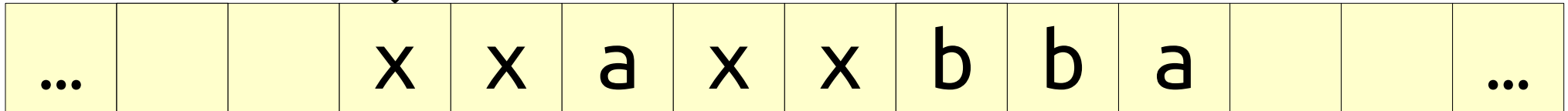
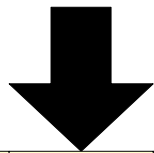
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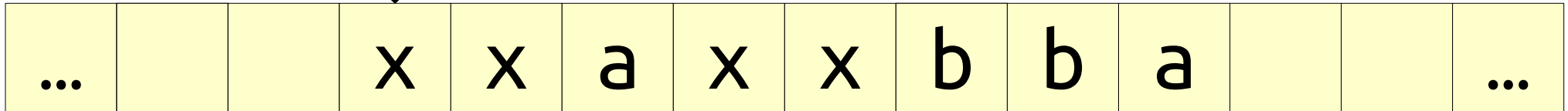
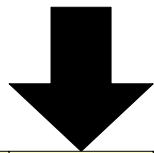


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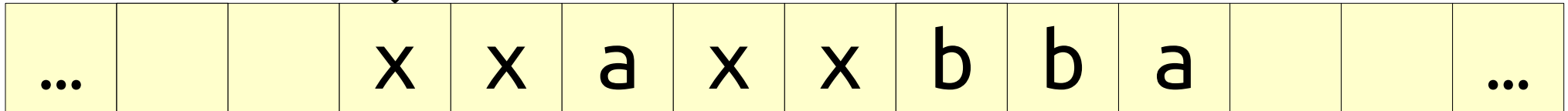
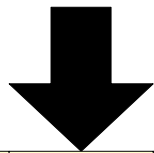
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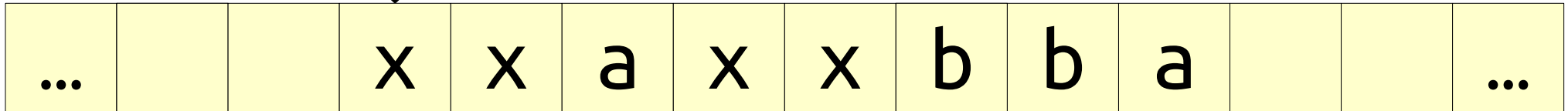
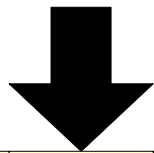
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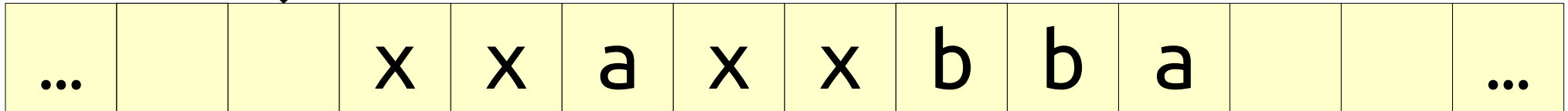
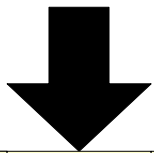
LoopA:

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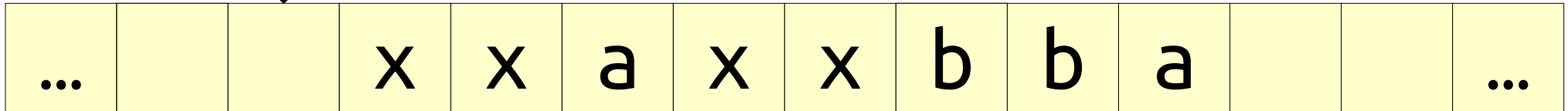
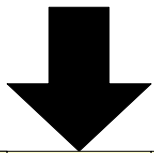


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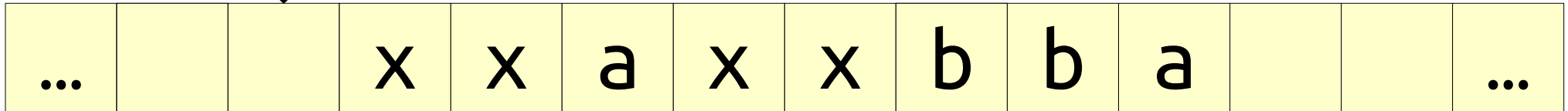
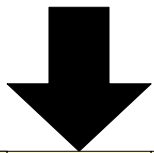


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```

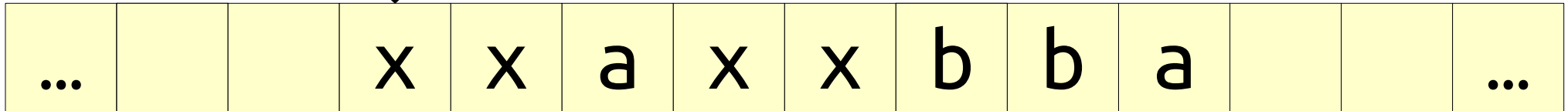
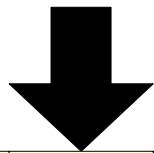


```
Start:  
  If 'a' Goto FoundA  
  Move Right  
  Goto Start
```

```
FoundA:  
  Write 'x'
```

```
LoopA:  
  Move Right  
  If 'a' Goto LoopA  
  If 'x' Goto LoopA  
  Write 'x'  
  Goto GoHome
```

```
GoHome:  
  Move Left  
  If Not Blank Goto GoHome  
  Move Right  
  Goto Start
```

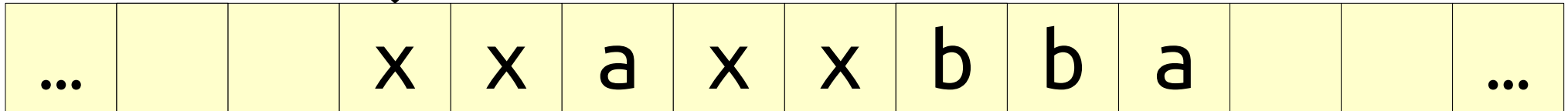
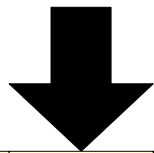


```
Start:  
  If 'a' Goto FoundA  
  Move Right  
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  If 'a' Goto LoopA  
  If 'x' Goto LoopA  
  Write 'x'  
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```
GoHome:  
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  Goto Start
```



Start:

```
If 'a' Goto FoundA  
Move Right  
Goto Start
```

FoundA:

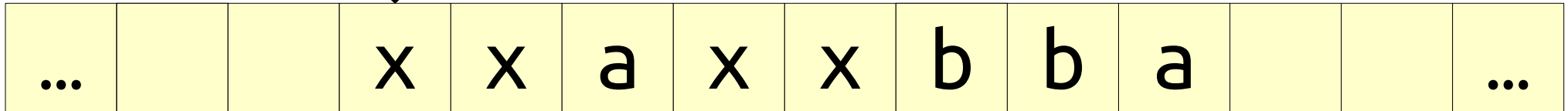
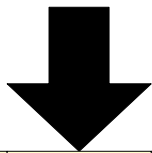
```
Write 'x'
```

LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

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Move Left  
If Not Blank Goto GoHome  
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```



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

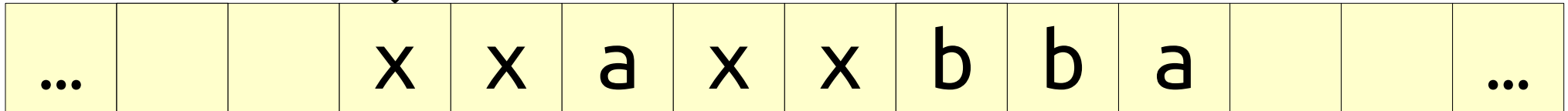
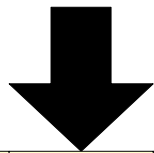
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



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If 'a' Goto FoundA

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If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

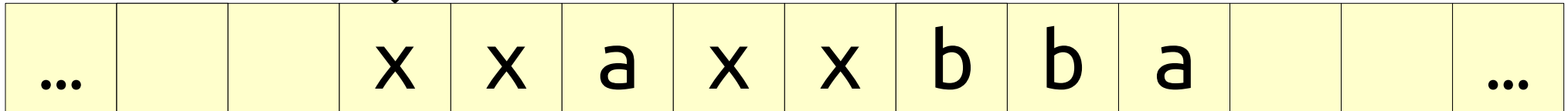
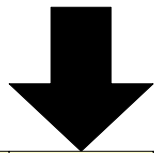
GoHome:

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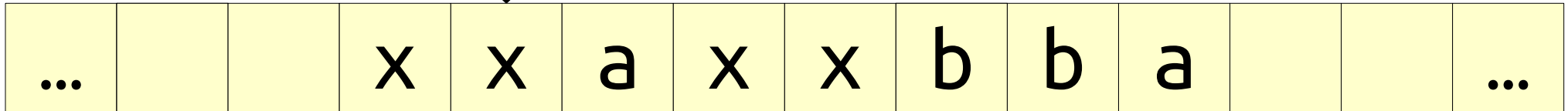
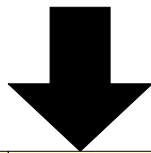
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

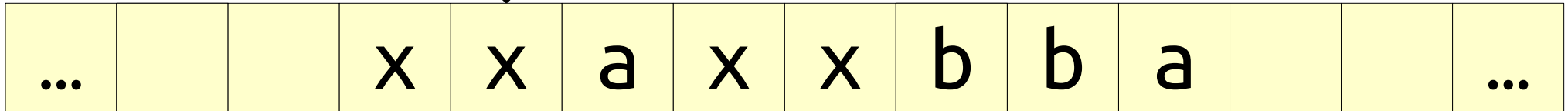
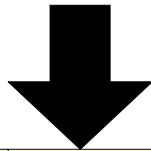
Goto Start



```
Start:  
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```

```
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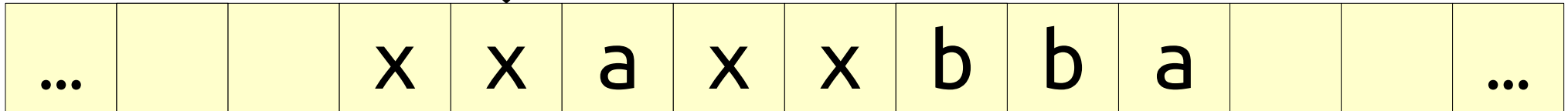
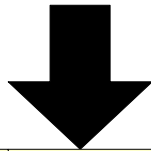
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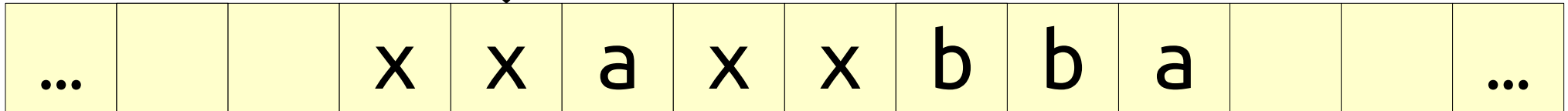
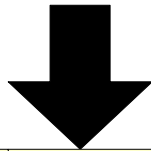
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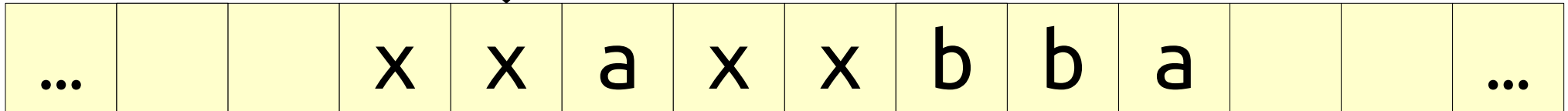
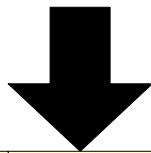
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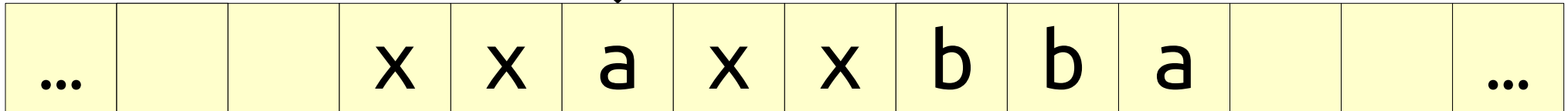
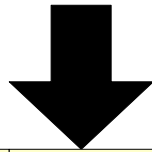
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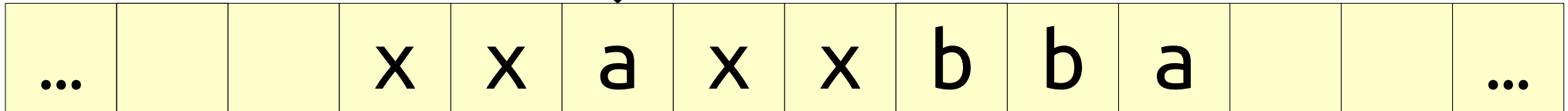
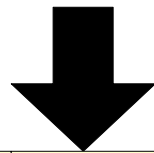
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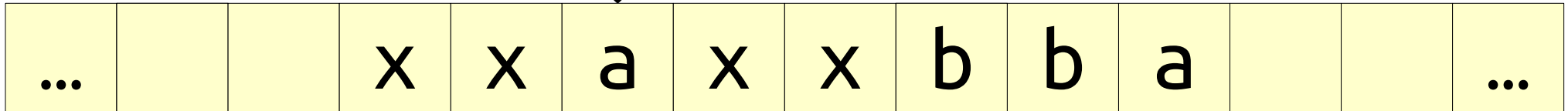
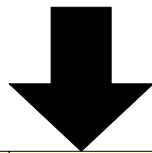
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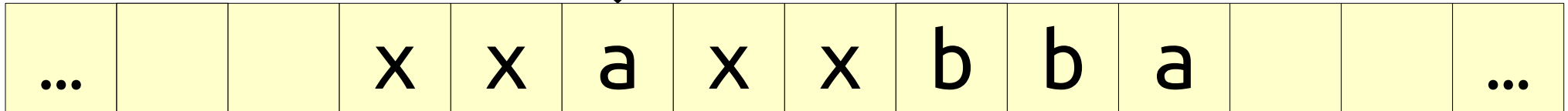
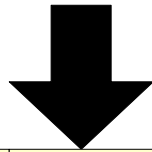
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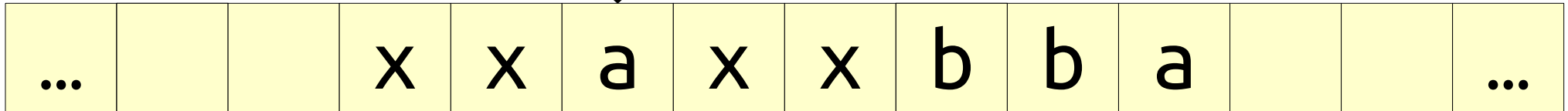
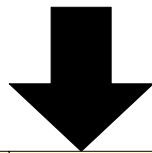


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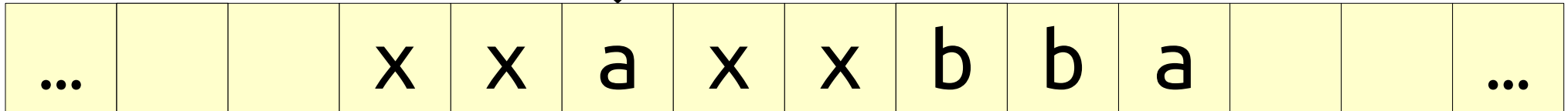
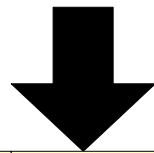
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```

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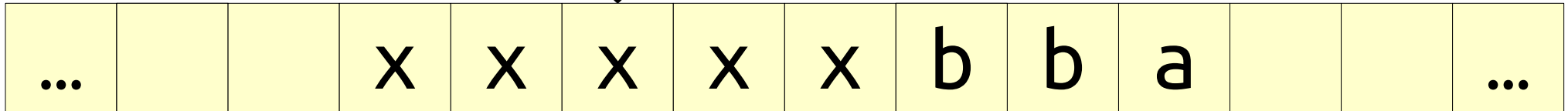
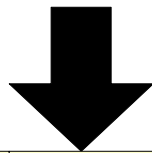
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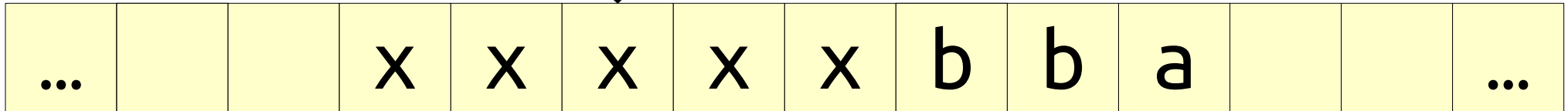
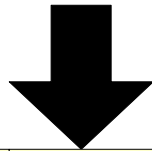
```
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```

LoopA:

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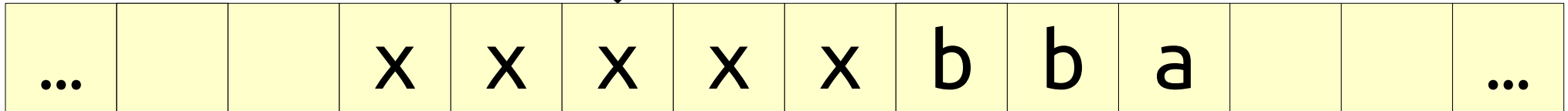
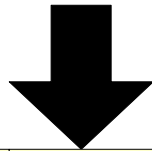
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```

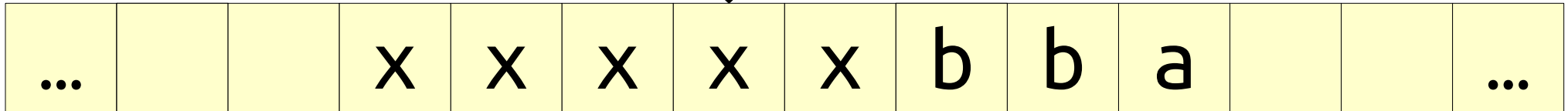
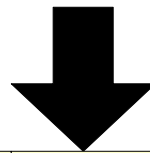
GoHome:

```
Move Left
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Goto Start
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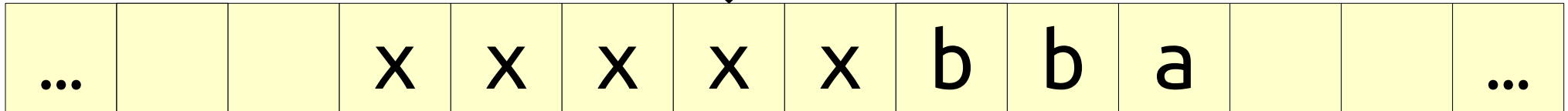
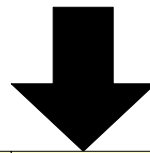
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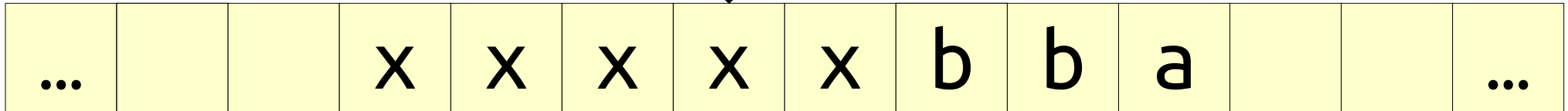
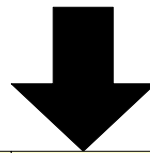
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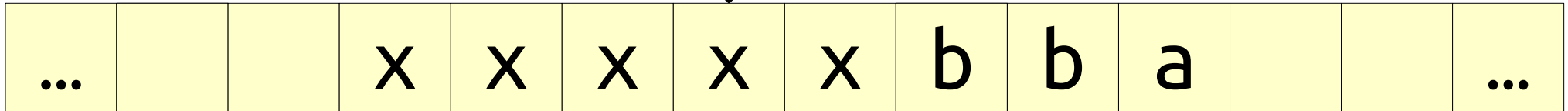
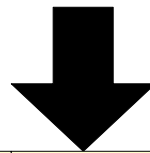
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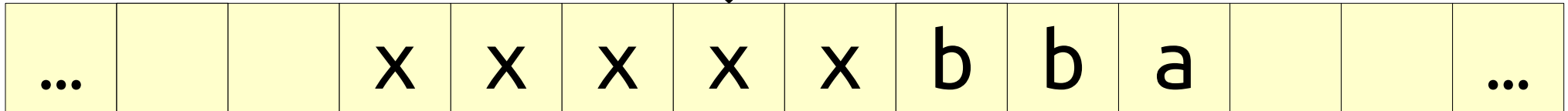
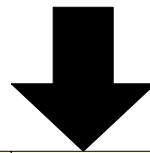
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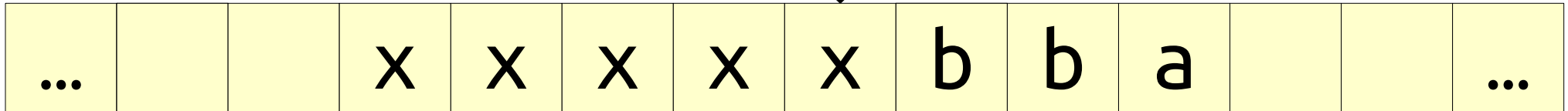
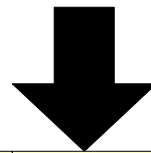
GoHome:

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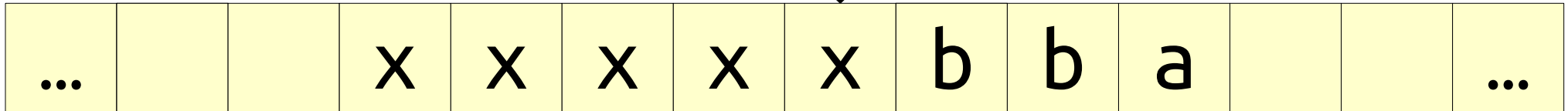
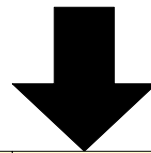


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```

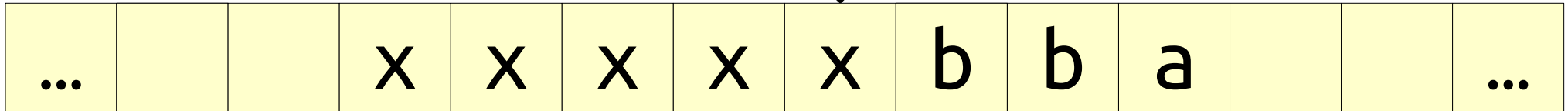
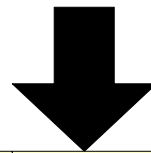
GoHome:

```
Move Left
```

```
If Not Blank Goto GoHome
```

```
Move Right
```

```
Goto Start
```

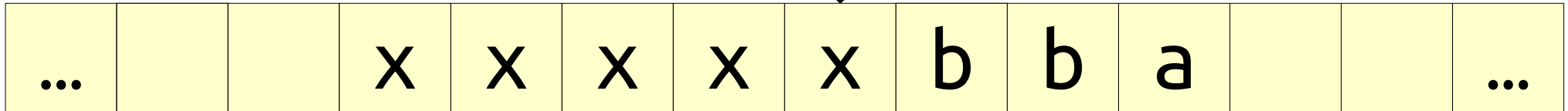
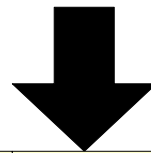


```
Start:  
  If 'a' Goto FoundA  
  Move Right  
  Goto Start
```

```
FoundA:  
  Write 'x'
```

```
LoopA:  
  Move Right  
  If 'a' Goto LoopA  
  If 'x' Goto LoopA  
  Write 'x'  
  Goto GoHome
```

```
GoHome:  
  Move Left  
  If Not Blank Goto GoHome  
  Move Right  
  Goto Start
```



Start:

```
If 'a' Goto FoundA  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right
```

```
If 'a' Goto LoopA
```

```
If 'x' Goto LoopA
```

```
Write 'x'
```

```
Goto GoHome
```

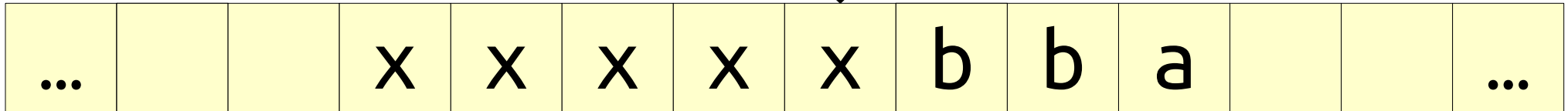
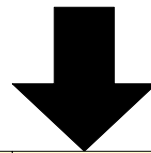
GoHome:

```
Move Left
```

```
If Not Blank Goto GoHome
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```
Move Right
```

```
Goto Start
```



Start:

```
If 'a' Goto FoundA  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right
```

```
If 'a' Goto LoopA
```

```
If 'x' Goto LoopA
```

```
Write 'x'
```

```
Goto GoHome
```

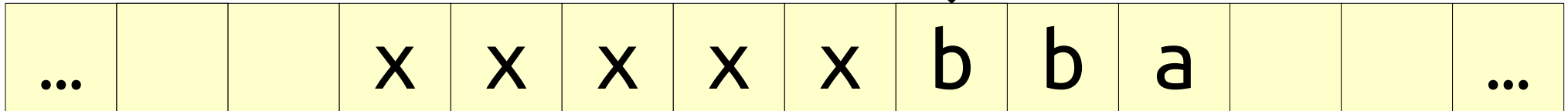
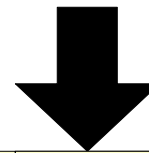
GoHome:

```
Move Left
```

```
If Not Blank Goto GoHome
```

```
Move Right
```

```
Goto Start
```



Start:

```
If 'a' Goto FoundA  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right
```

```
If 'a' Goto LoopA
```

```
If 'x' Goto LoopA
```

```
Write 'x'
```

```
Goto GoHome
```

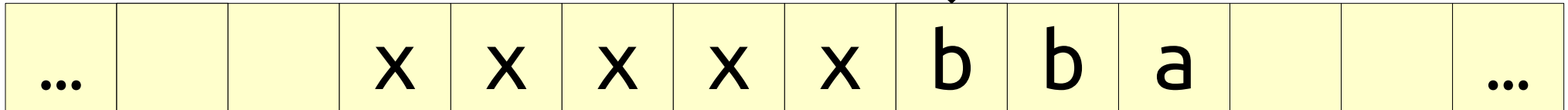
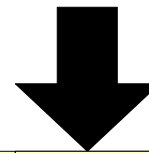
GoHome:

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Goto Start
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If 'a' Goto LoopA
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If 'x' Goto LoopA
```

```
Write 'x'
```

```
Goto GoHome
```

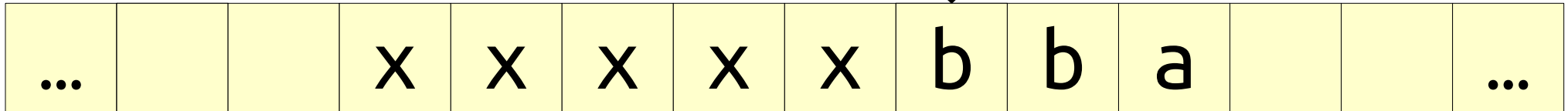
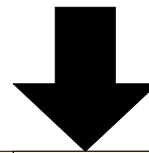
GoHome:

```
Move Left
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If Not Blank Goto GoHome
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Move Right
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```
Goto Start
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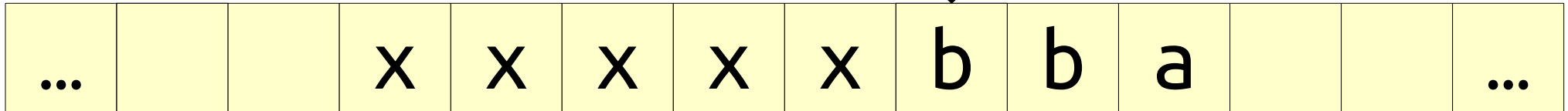
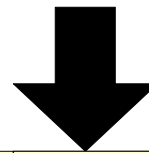


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GoHome:  
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  If Not Blank Goto GoHome  
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  Goto Start
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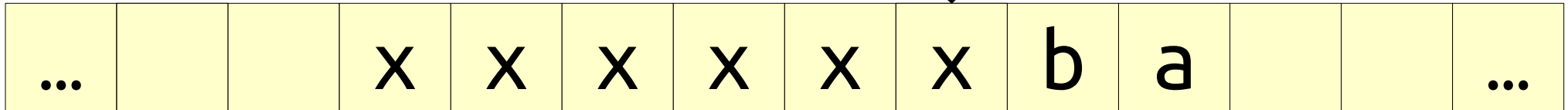
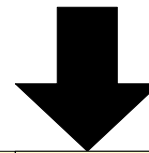


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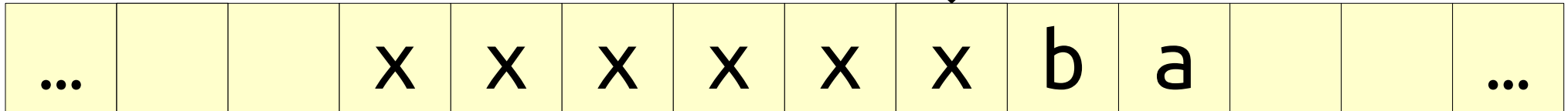
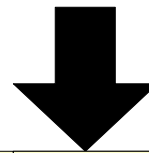


```
Start:  
  If 'a' Goto FoundA  
  Move Right  
  Goto Start
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  Write 'x'  
  Goto GoHome
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GoHome:  
  Move Left  
  If Not Blank Goto GoHome  
  Move Right  
  Goto Start
```



Start:

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If 'a' Goto FoundA  
Move Right  
Goto Start
```

FoundA:

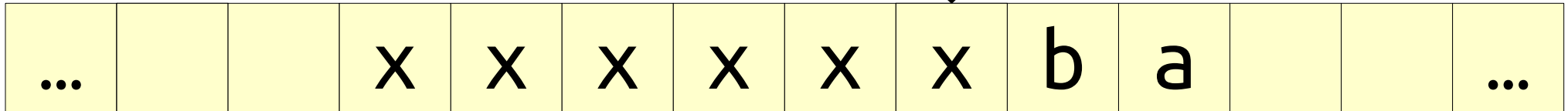
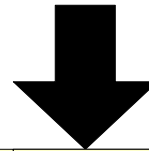
```
Write 'x'
```

LoopA:

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Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
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If Not Blank Goto GoHome  
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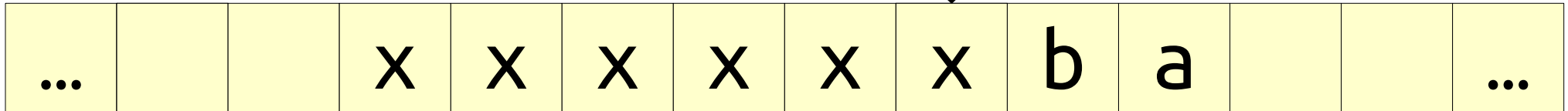
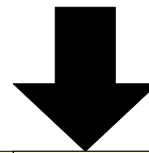
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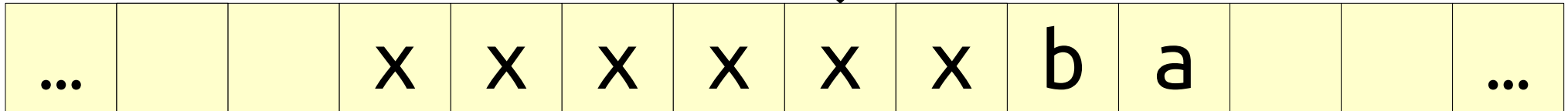
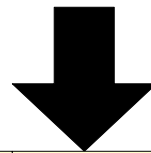
LoopA:

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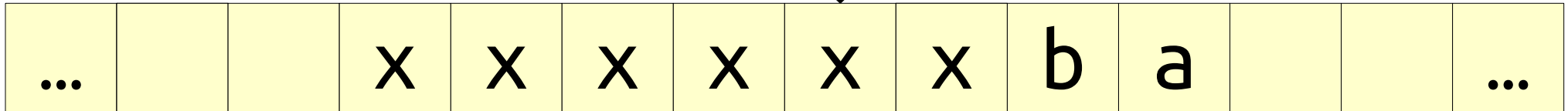
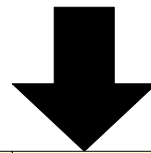


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FoundA:

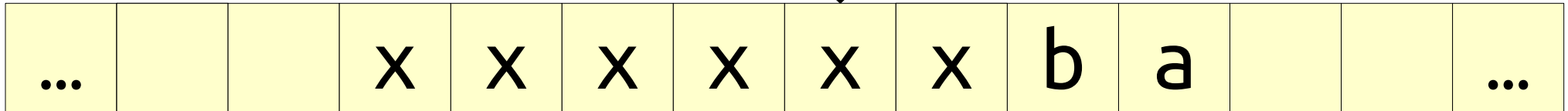
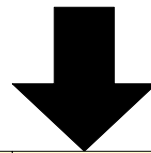
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Move Right  
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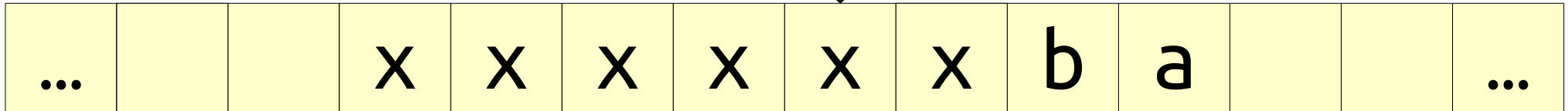
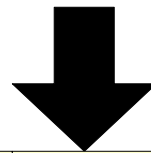
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If 'a' Goto FoundA  
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```

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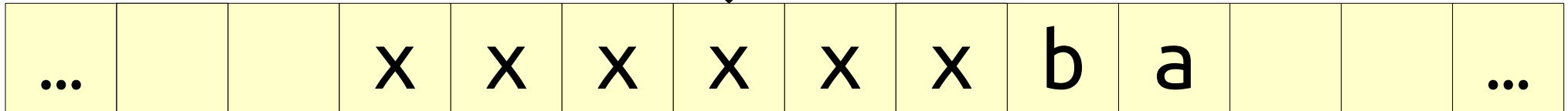
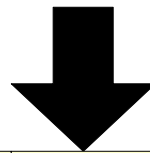
LoopA:

```
Move Right  
If 'a' Goto LoopA  
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```

GoHome:

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```
If Not Blank Goto GoHome  
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Goto Start
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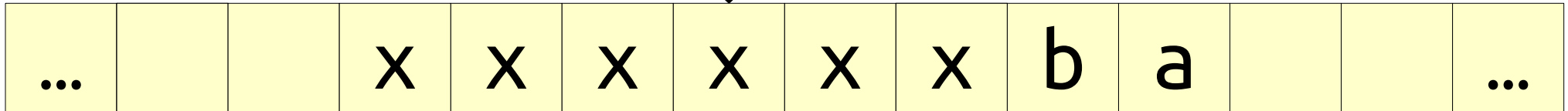
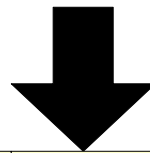


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FoundA:

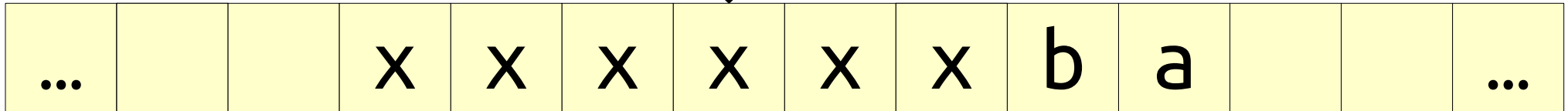
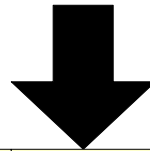
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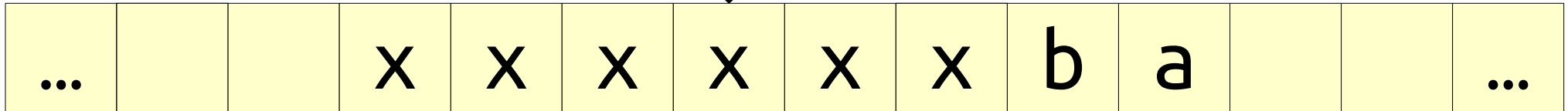
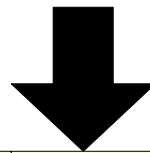
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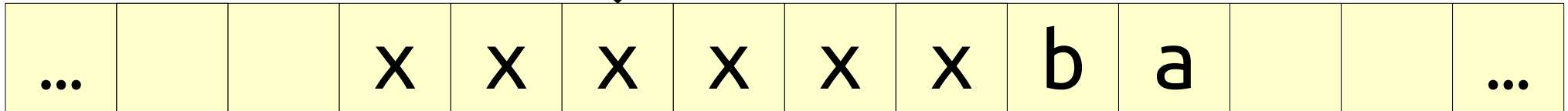
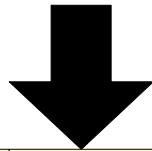
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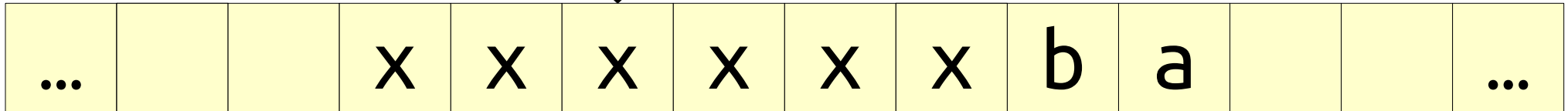
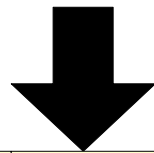
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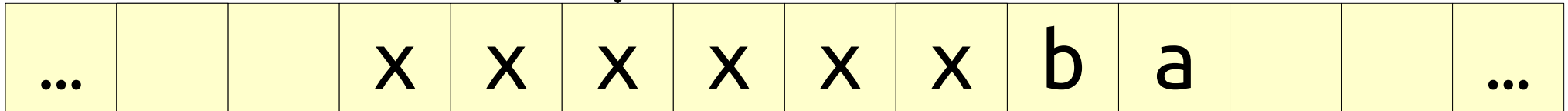
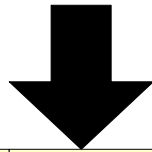
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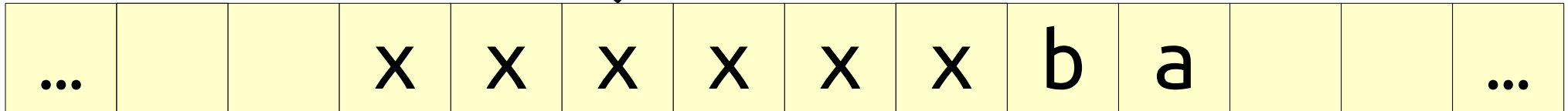
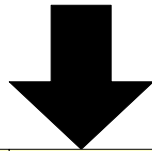
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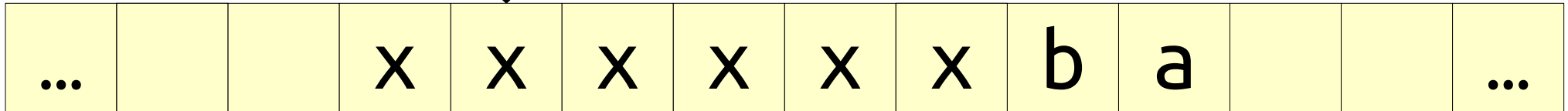
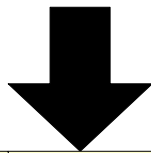
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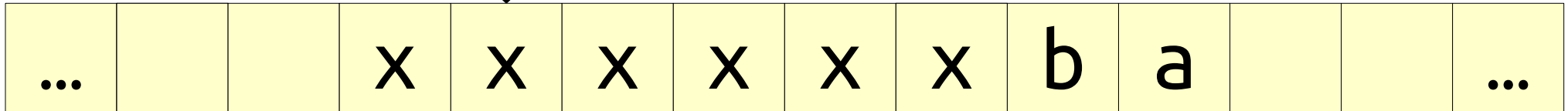
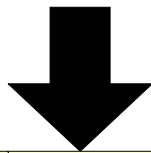


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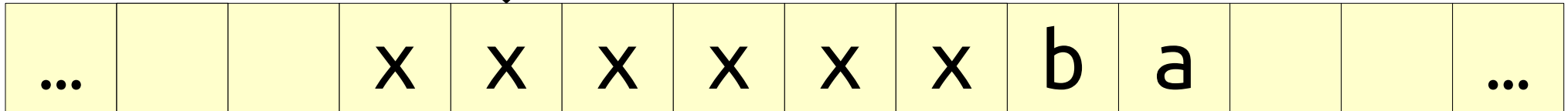
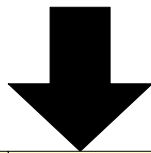
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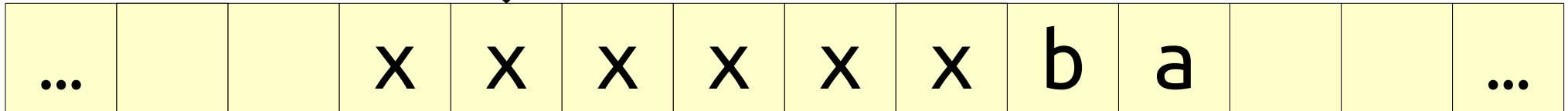
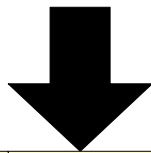
LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

```
Move Left
```

```
If Not Blank Goto GoHome  
Move Right  
Goto Start
```



Start:

```
If 'a' Goto FoundA  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

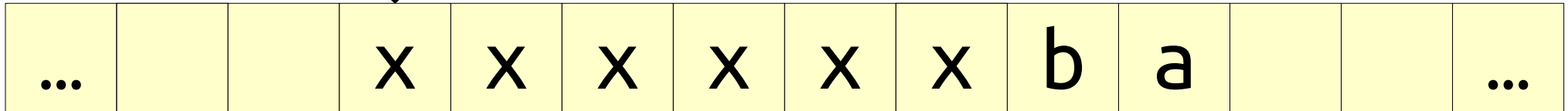
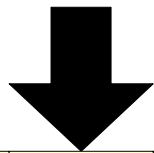
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GoHome:

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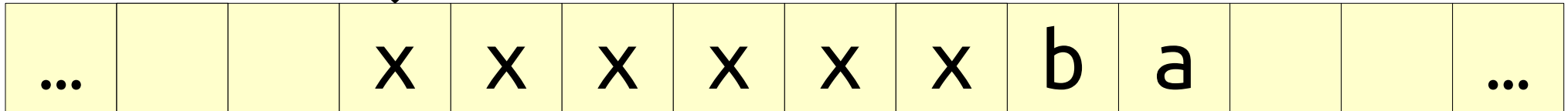
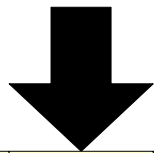


```
Start:  
  If 'a' Goto FoundA  
  Move Right  
  Goto Start
```

```
FoundA:  
  Write 'x'
```

```
LoopA:  
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GoHome:  
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Start:

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FoundA:

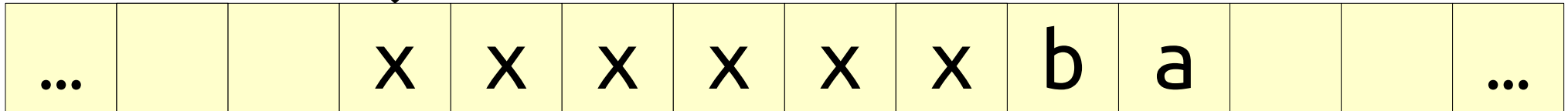
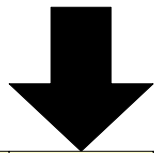
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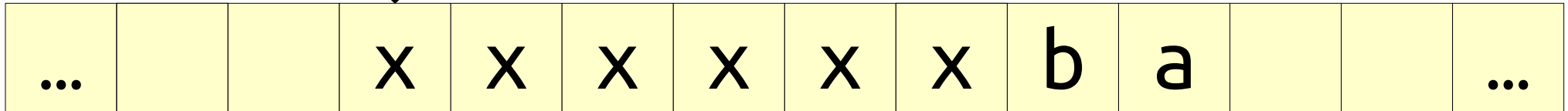
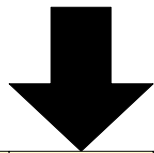
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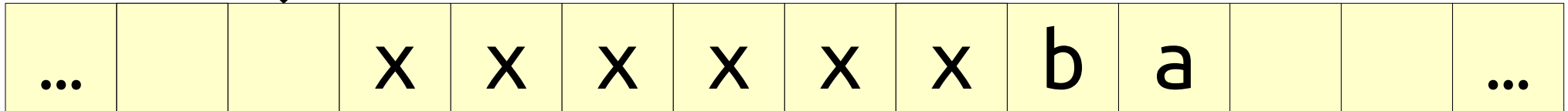
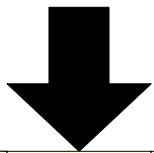
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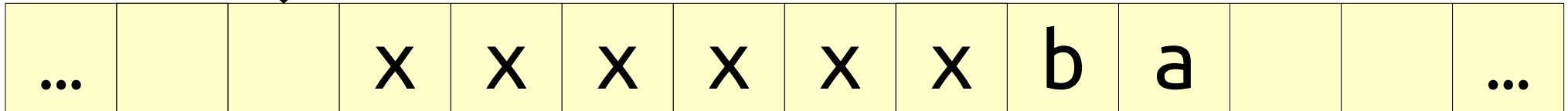
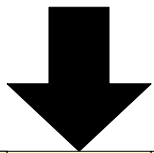


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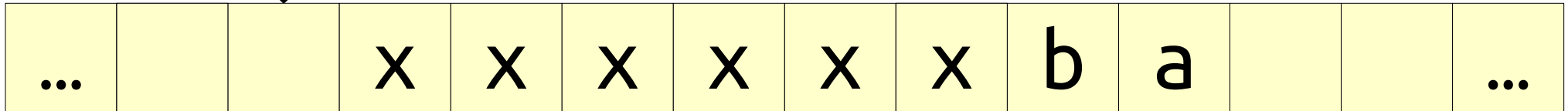
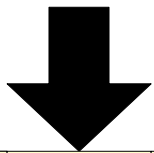


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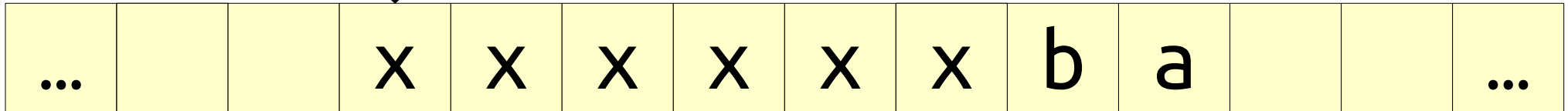
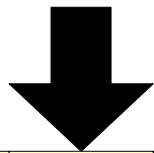


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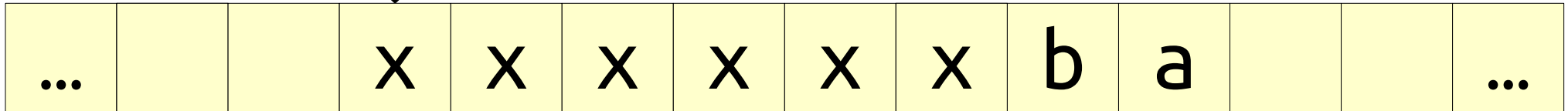
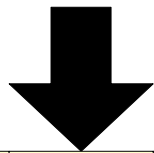


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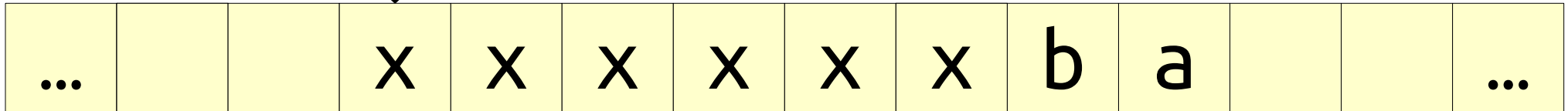
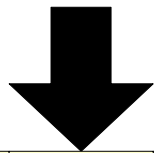
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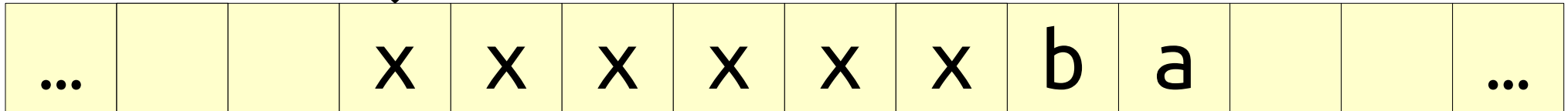
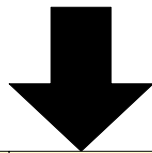
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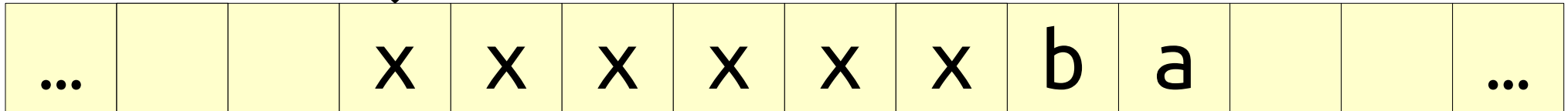
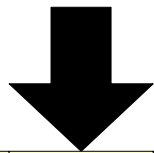
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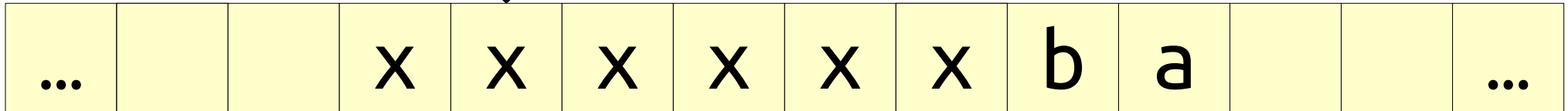
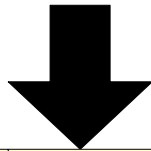
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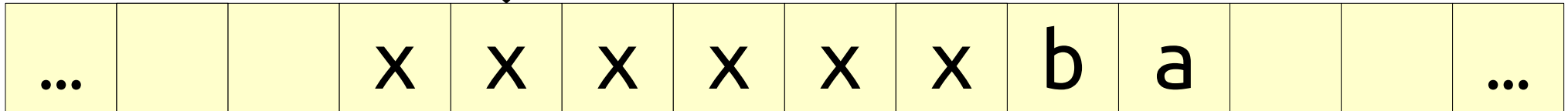
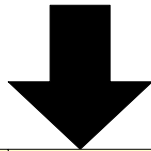
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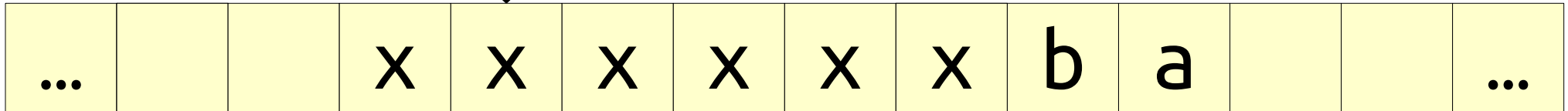
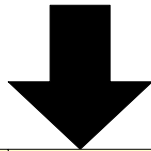
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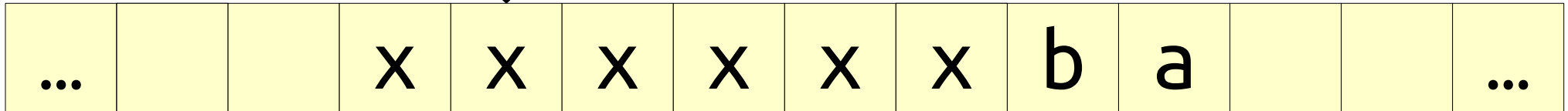
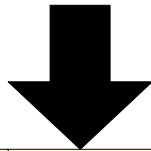
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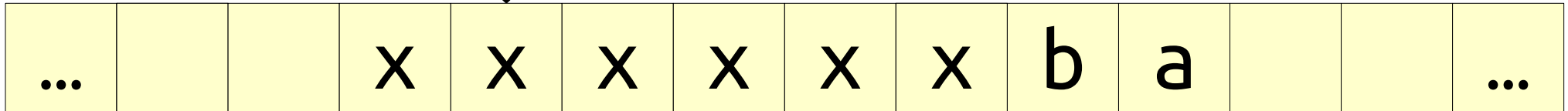
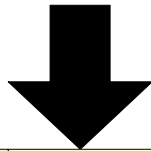
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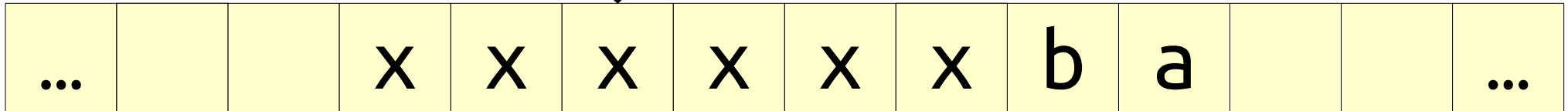
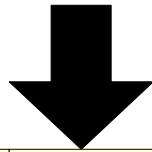
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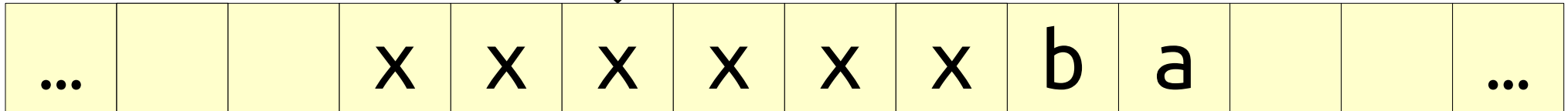
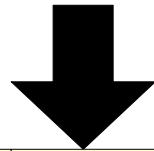
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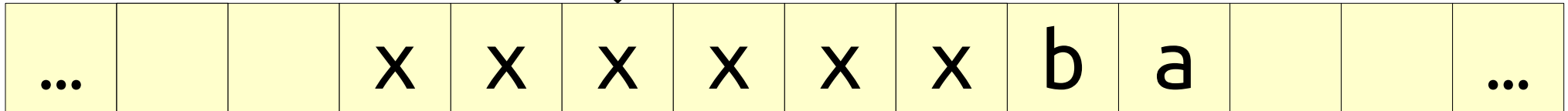
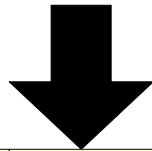
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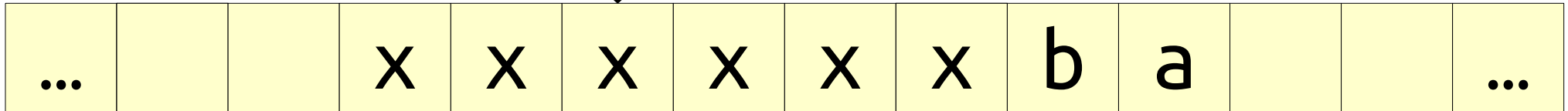
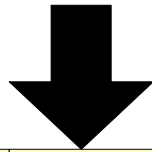
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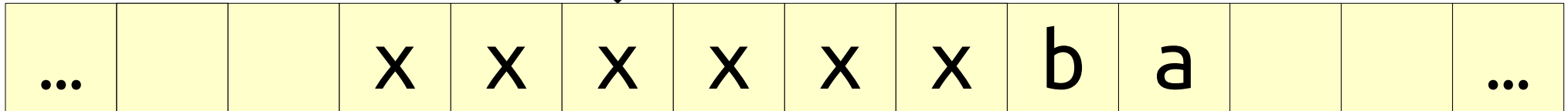
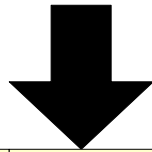
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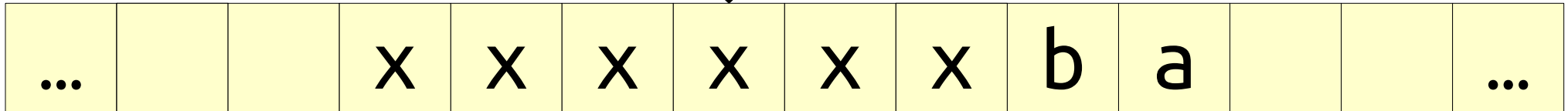
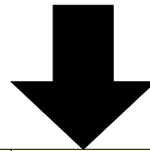
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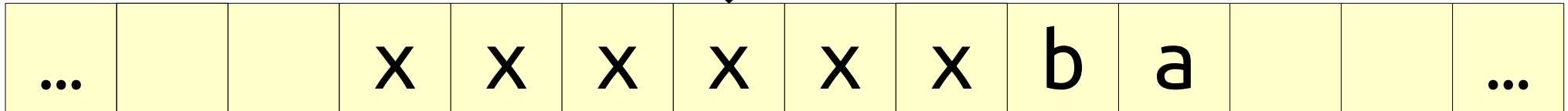
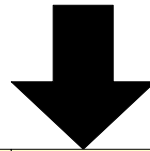
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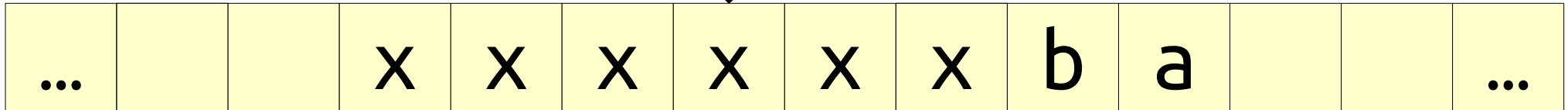
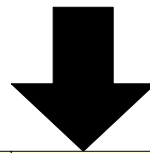
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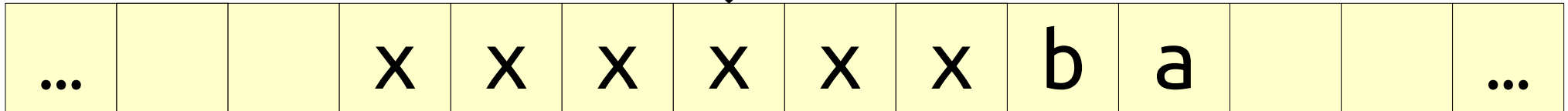
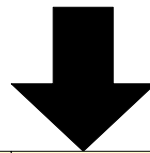
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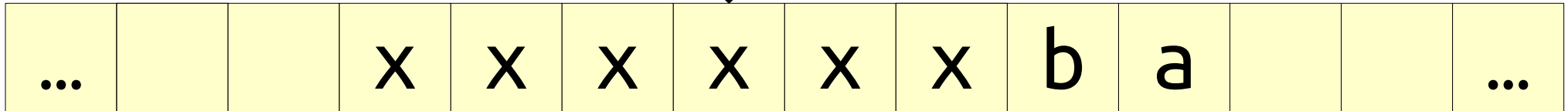
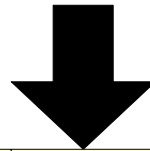
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If 'x' Goto LoopA

Write 'x'

Goto GoHome

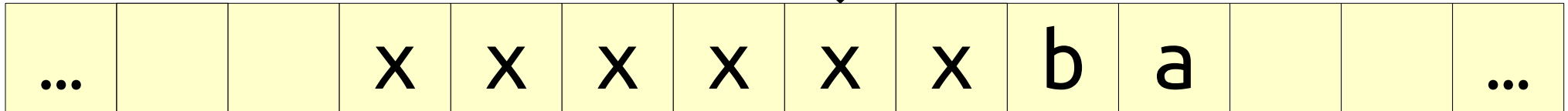
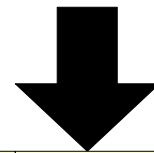
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

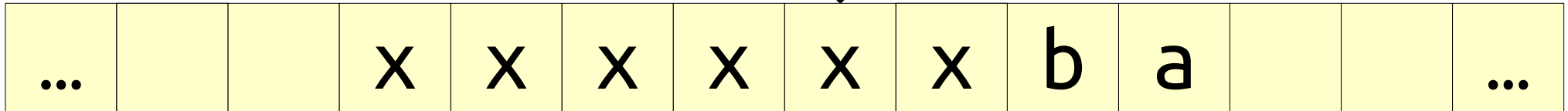
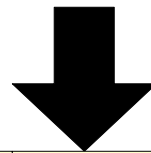
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

```
If 'a' Goto FoundA  
Move Right  
Goto Start
```

FoundA:

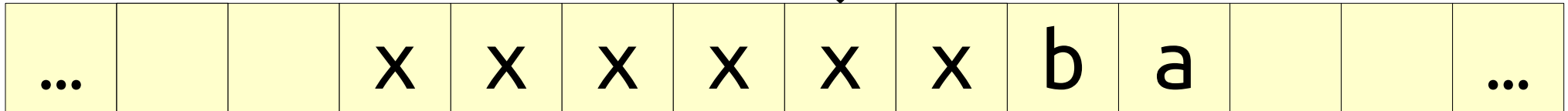
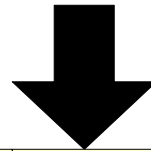
```
Write 'x'
```

LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

```
Move Left  
If Not Blank Goto GoHome  
Move Right  
Goto Start
```



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

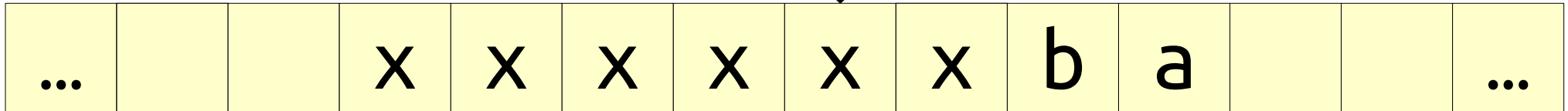
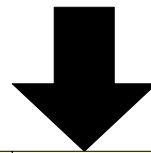
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

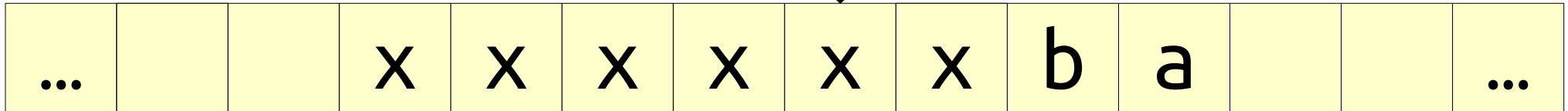
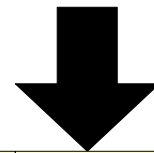
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

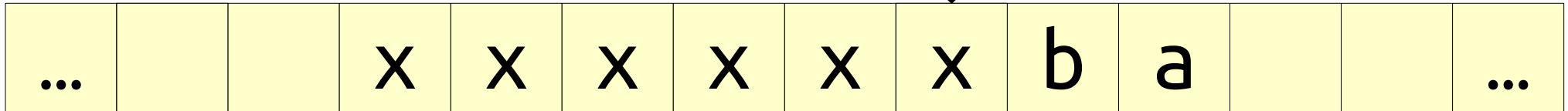
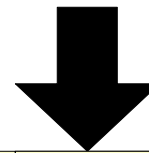
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

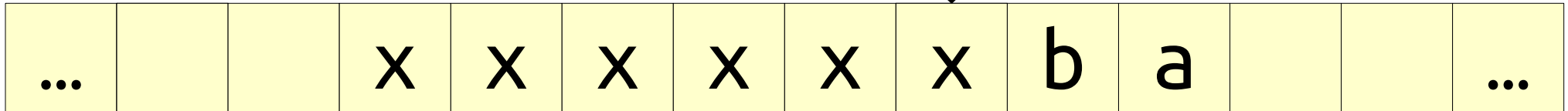
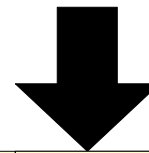
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

```
If 'a' Goto FoundA  
Move Right  
Goto Start
```

FoundA:

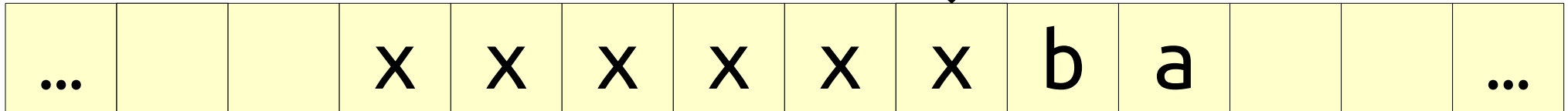
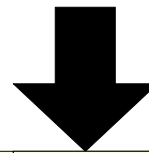
```
Write 'x'
```

LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

```
Move Left  
If Not Blank Goto GoHome  
Move Right  
Goto Start
```



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

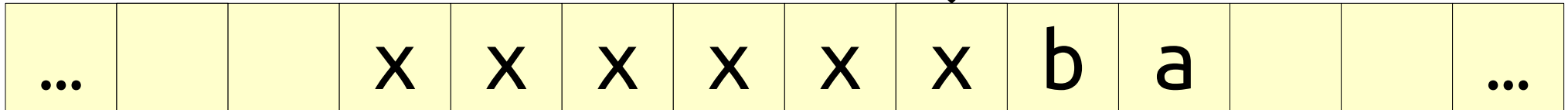
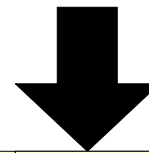
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

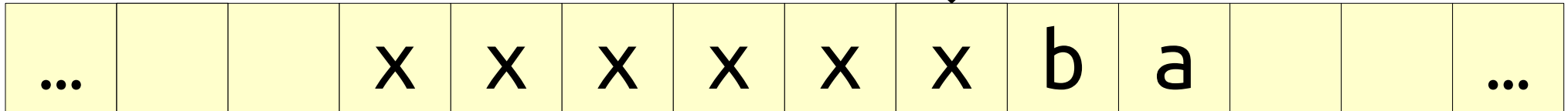
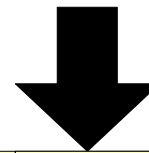
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

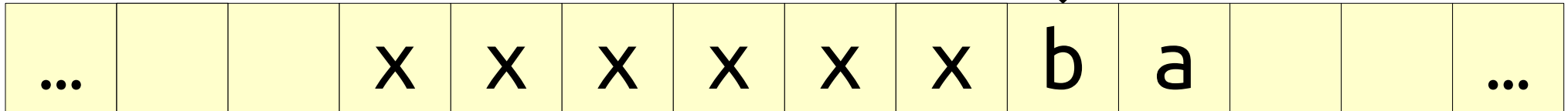
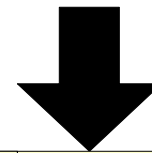
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

```
If 'a' Goto FoundA  
Move Right  
Goto Start
```

FoundA:

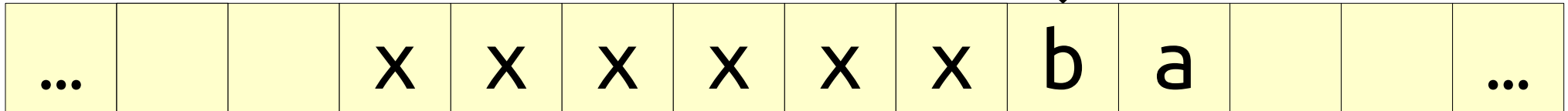
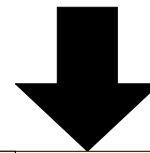
```
Write 'x'
```

LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

```
Move Left  
If Not Blank Goto GoHome  
Move Right  
Goto Start
```



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

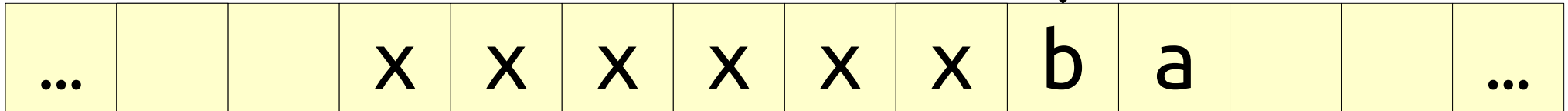
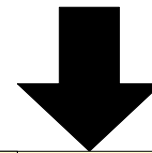
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA

Move Right
Goto Start

FoundA:

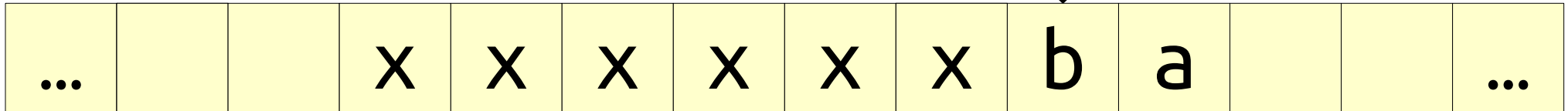
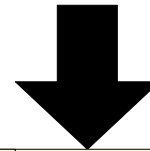
Write 'x'

LoopA:

Move Right
If 'a' Goto LoopA
If 'x' Goto LoopA
Write 'x'
Goto GoHome

GoHome:

Move Left
If Not Blank Goto GoHome
Move Right
Goto Start



Start:

If 'a' Goto FoundA

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

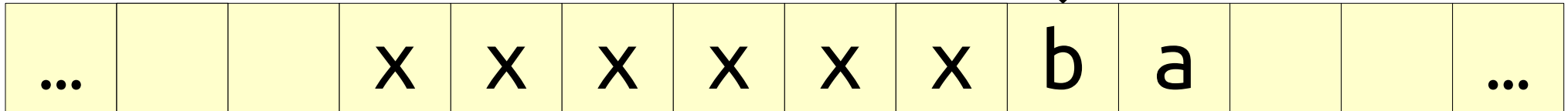
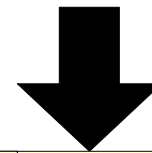
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

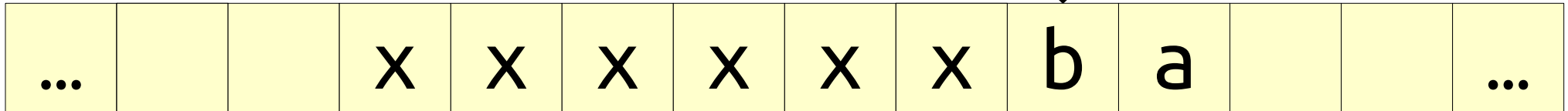
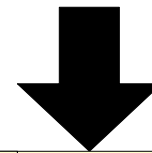
GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

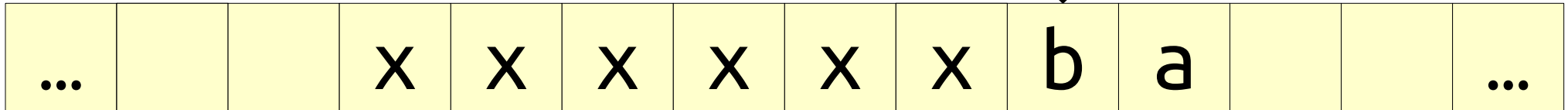
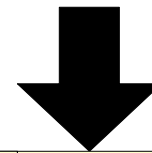
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome

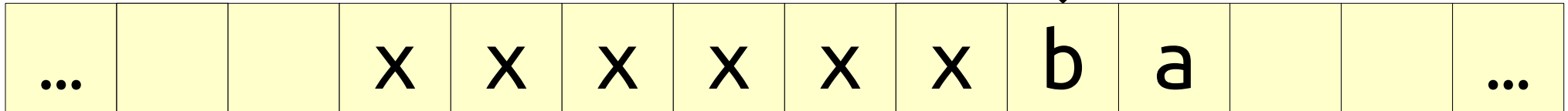
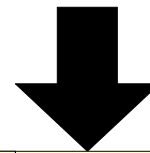


```
Start:
  If 'a' Goto FoundA
  If 'b' Goto FoundB
  Move Right
  Goto Start
```

```
FoundA:
  Write 'x'
LoopA:
  Move Right
  If 'a' Goto LoopA
  If 'x' Goto LoopA
  Write 'x'
  Goto GoHome
```

```
GoHome:
  Move Left
  If Not Blank Goto GoHome
  Move Right
  Goto Start
```

```
FoundB:
  Write 'x'
LoopB:
  Move Right
  If 'b' Goto LoopB
  If 'x' Goto LoopB
  Write 'x'
  Goto GoHome
```

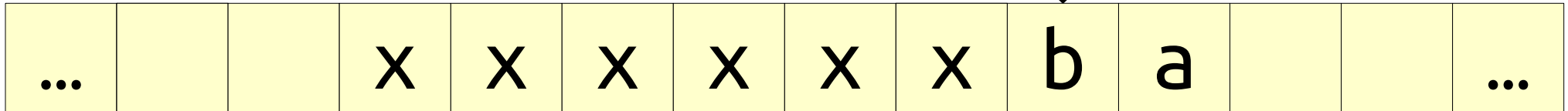
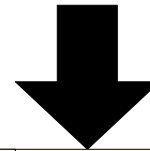


```
Start:
  If 'a' Goto FoundA
  If 'b' Goto FoundB
  Move Right
  Goto Start
```

```
FoundA:
  Write 'x'
LoopA:
  Move Right
  If 'a' Goto LoopA
  If 'x' Goto LoopA
  Write 'x'
  Goto GoHome
```

```
GoHome:
  Move Left
  If Not Blank Goto GoHome
  Move Right
  Goto Start
```

```
FoundB:
  Write 'x'
LoopB:
  Move Right
  If 'b' Goto LoopB
  If 'x' Goto LoopB
  Write 'x'
  Goto GoHome
```



Start:

```
If 'a' Goto FoundA  
If 'b' Goto FoundB  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

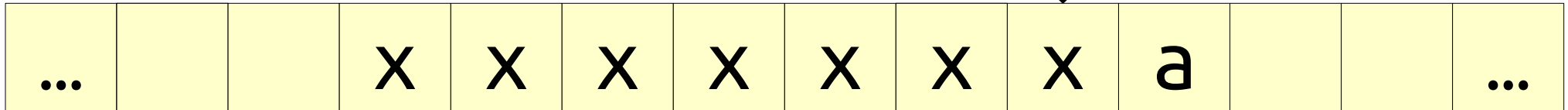
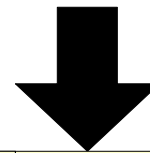
```
Move Left  
If Not Blank Goto GoHome  
Move Right  
Goto Start
```

FoundB:

```
Write 'x'
```

LoopB:

```
Move Right  
If 'b' Goto LoopB  
If 'x' Goto LoopB  
Write 'x'  
Goto GoHome
```

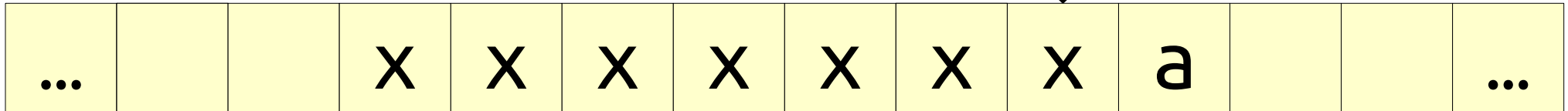
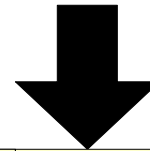


```
Start:
  If 'a' Goto FoundA
  If 'b' Goto FoundB
  Move Right
  Goto Start
```

```
FoundA:
  Write 'x'
LoopA:
  Move Right
  If 'a' Goto LoopA
  If 'x' Goto LoopA
  Write 'x'
  Goto GoHome
```

```
GoHome:
  Move Left
  If Not Blank Goto GoHome
  Move Right
  Goto Start
```

```
FoundB:
  Write 'x'
LoopB:
  Move Right
  If 'b' Goto LoopB
  If 'x' Goto LoopB
  Write 'x'
  Goto GoHome
```



Start:

```
If 'a' Goto FoundA  
If 'b' Goto FoundB  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

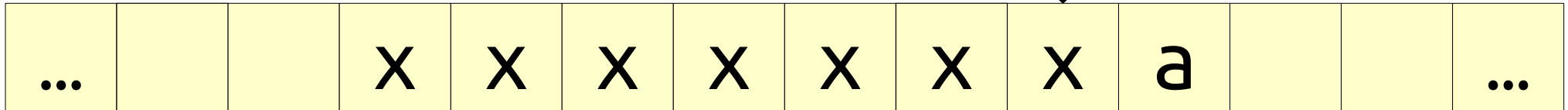
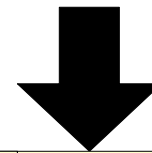
```
Move Left  
If Not Blank Goto GoHome  
Move Right  
Goto Start
```

FoundB:

```
Write 'x'
```

LoopB:

```
Move Right  
If 'b' Goto LoopB  
If 'x' Goto LoopB  
Write 'x'  
Goto GoHome
```



Start:

```
If 'a' Goto FoundA  
If 'b' Goto FoundB  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

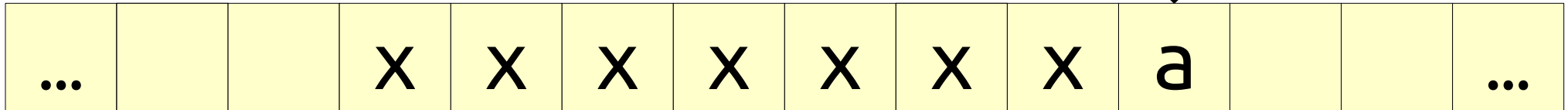
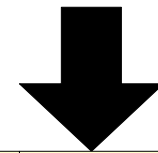
```
Move Left  
If Not Blank Goto GoHome  
Move Right  
Goto Start
```

FoundB:

```
Write 'x'
```

LoopB:

```
Move Right  
If 'b' Goto LoopB  
If 'x' Goto LoopB  
Write 'x'  
Goto GoHome
```



Start:

```
If 'a' Goto FoundA  
If 'b' Goto FoundB  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

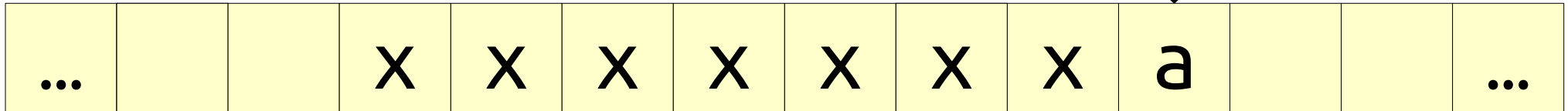
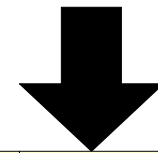
```
Move Left  
If Not Blank Goto GoHome  
Move Right  
Goto Start
```

FoundB:

```
Write 'x'
```

LoopB:

```
Move Right  
If 'b' Goto LoopB  
If 'x' Goto LoopB  
Write 'x'  
Goto GoHome
```



Start:

```
If 'a' Goto FoundA  
If 'b' Goto FoundB  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

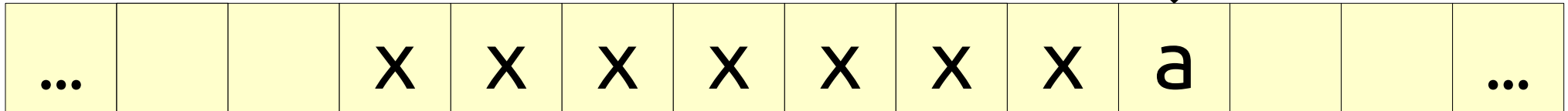
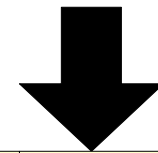
```
Move Left  
If Not Blank Goto GoHome  
Move Right  
Goto Start
```

FoundB:

```
Write 'x'
```

LoopB:

```
Move Right  
If 'b' Goto LoopB  
If 'x' Goto LoopB  
Write 'x'  
Goto GoHome
```



Start:

```
If 'a' Goto FoundA  
If 'b' Goto FoundB  
Move Right  
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right  
If 'a' Goto LoopA  
If 'x' Goto LoopA  
Write 'x'  
Goto GoHome
```

GoHome:

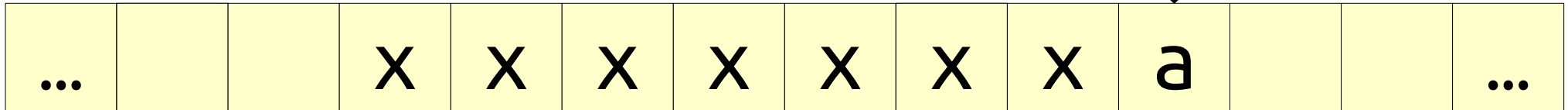
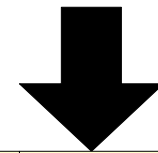
```
Move Left  
If Not Blank Goto GoHome  
Move Right  
Goto Start
```

FoundB:

```
Write 'x'
```

LoopB:

```
Move Right  
If 'b' Goto LoopB  
If 'x' Goto LoopB  
Write 'x'  
Goto GoHome
```



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

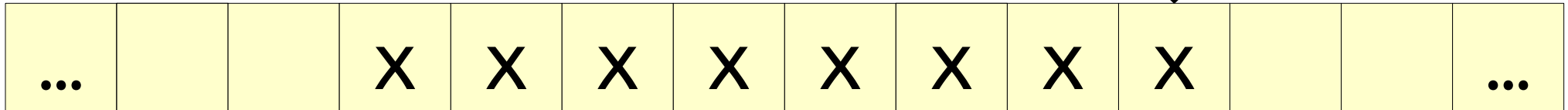
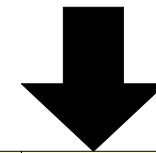
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

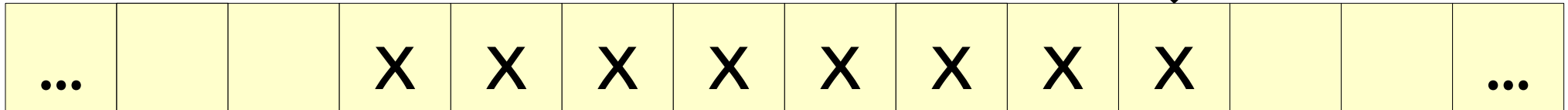
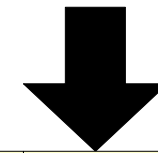
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Move Right

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

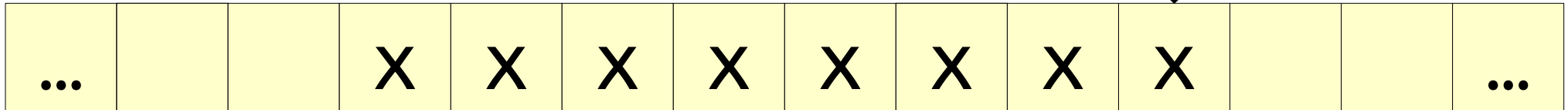
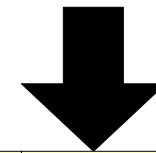
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

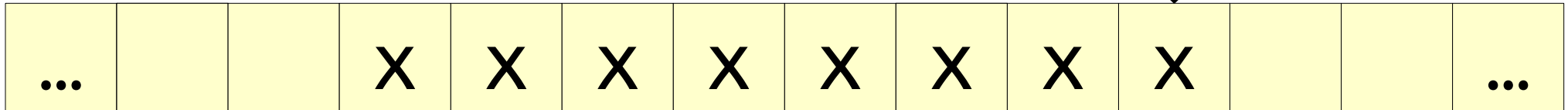
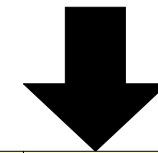
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

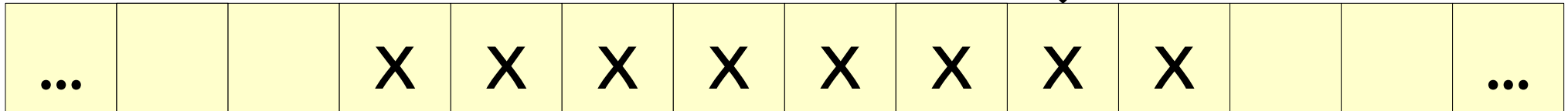
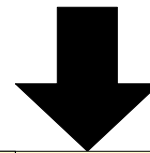
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

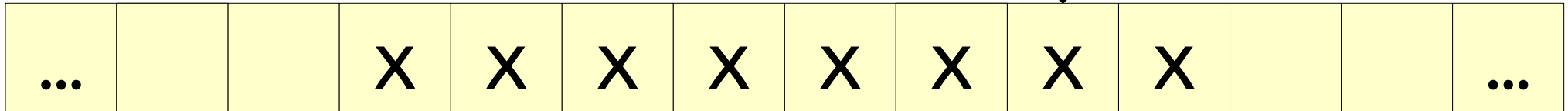
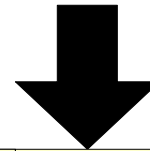
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

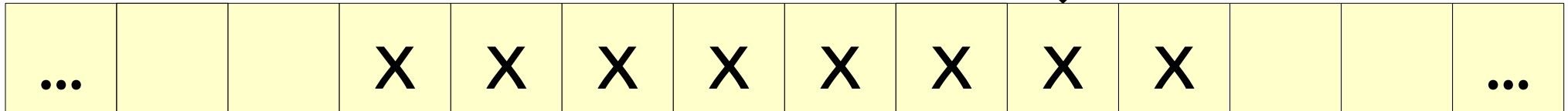
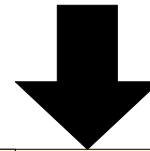
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

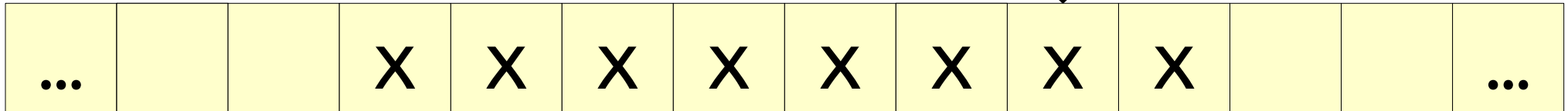
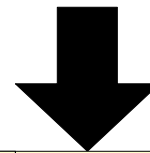
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

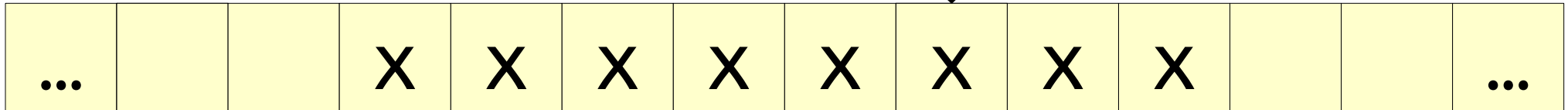
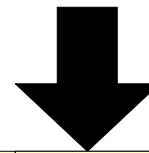
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

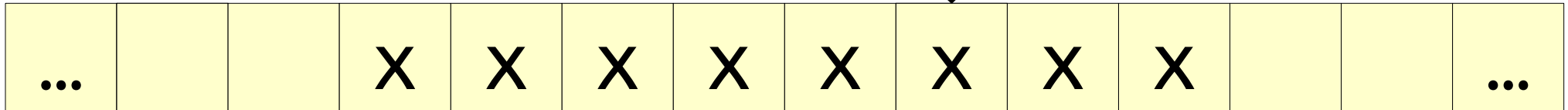
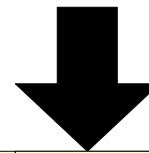
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Move Right

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

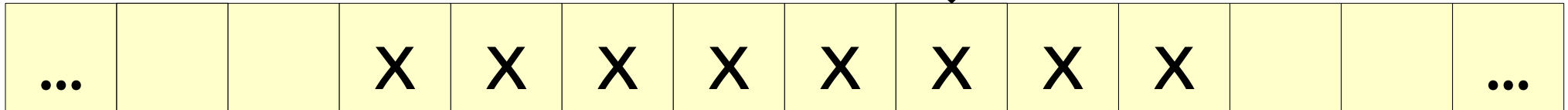
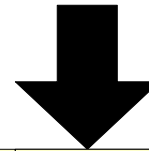
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

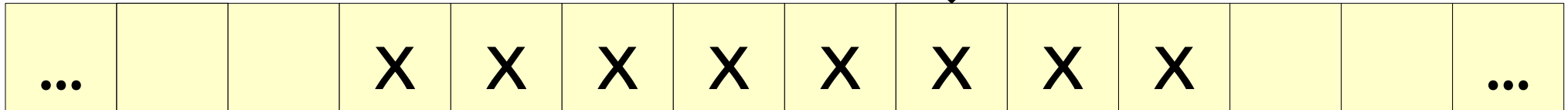
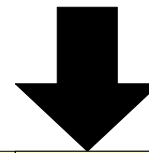
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Move Right

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

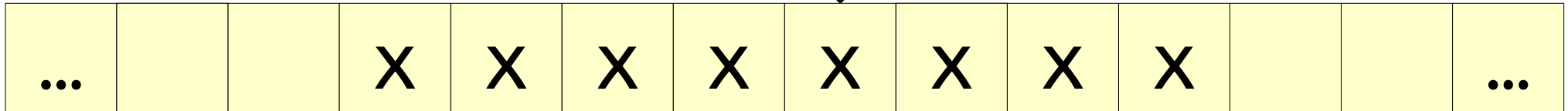
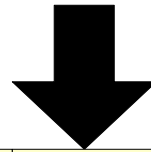
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

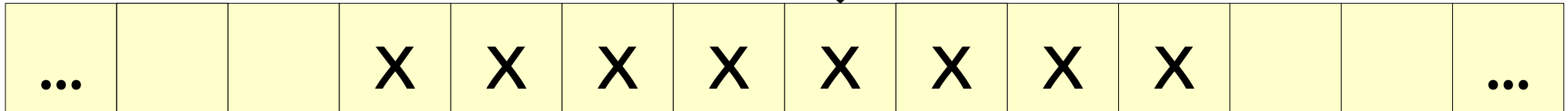
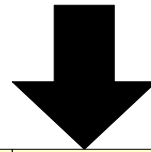
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Move Right

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

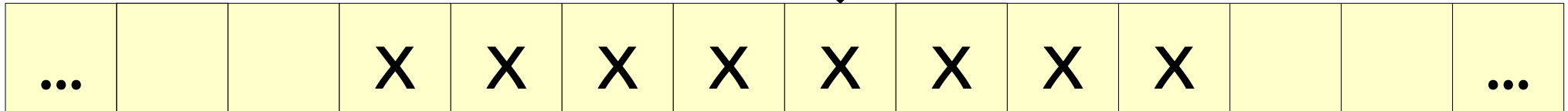
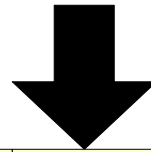
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Move Right

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

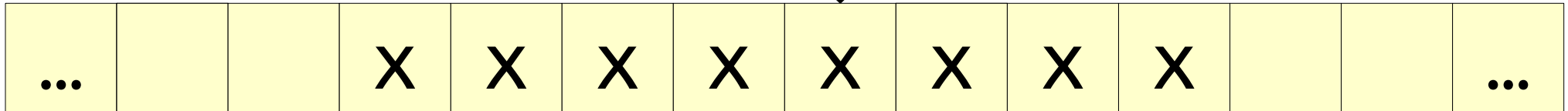
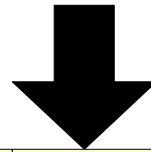
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

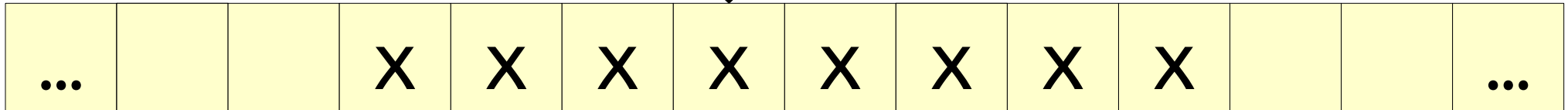
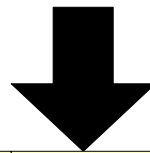
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

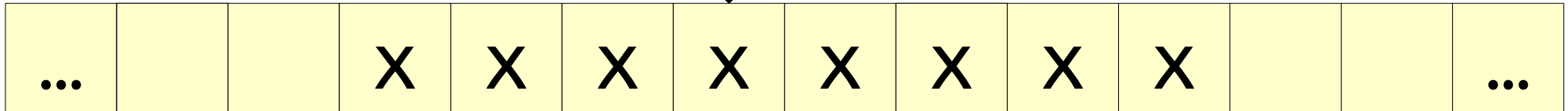
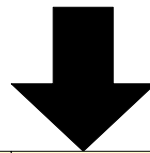
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Move Right

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

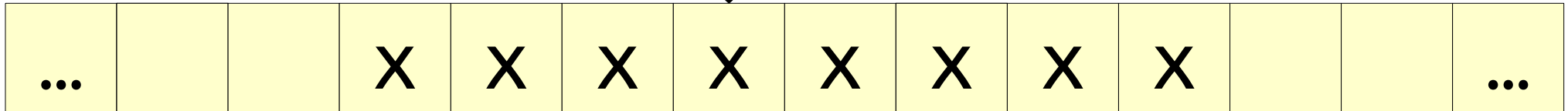
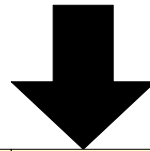
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

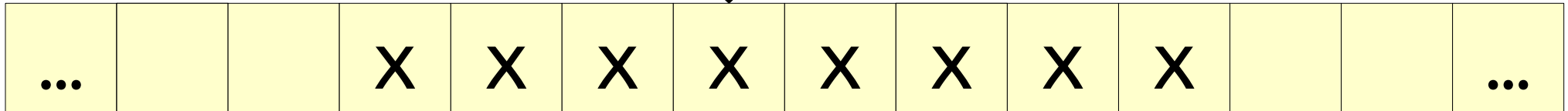
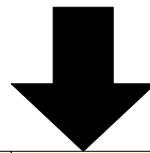
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

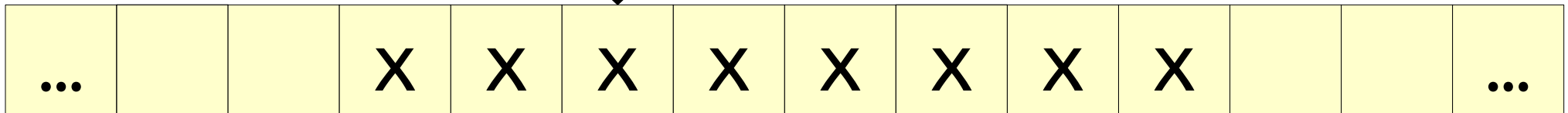
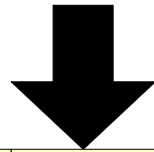
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Move Right

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

```
GoHome:
    Move Left
    If Not Blank Goto GoHome
    Move Right
    Goto Start
```

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

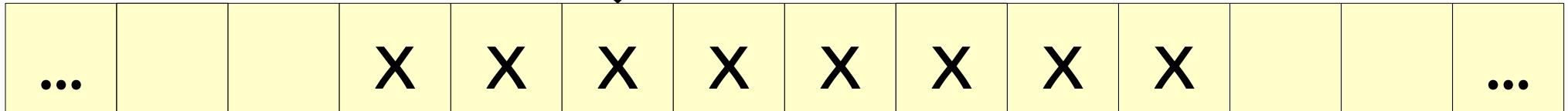
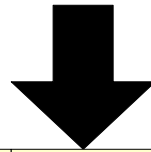
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

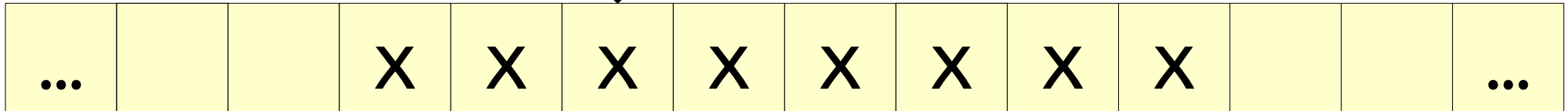
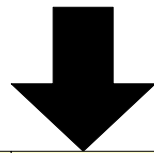
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Move Right

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

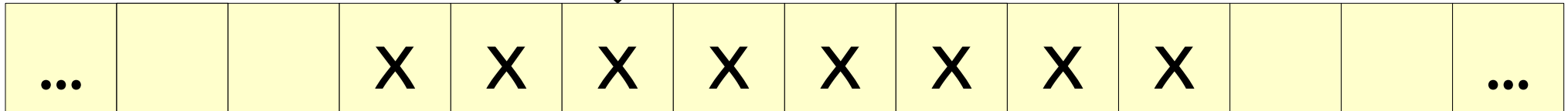
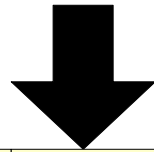
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

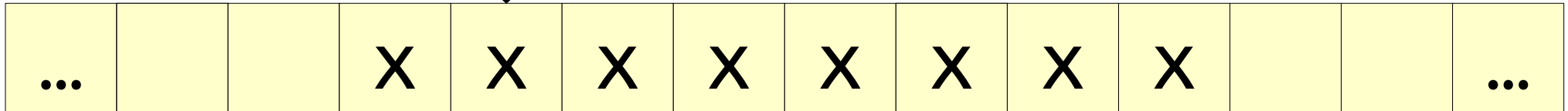
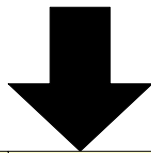
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

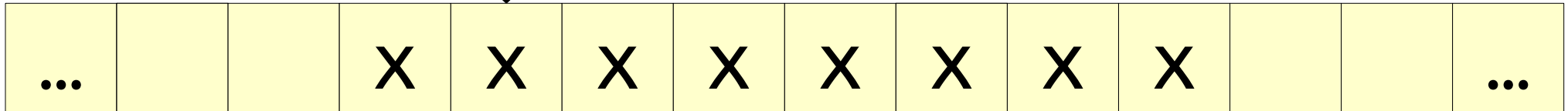
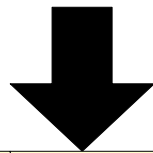
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

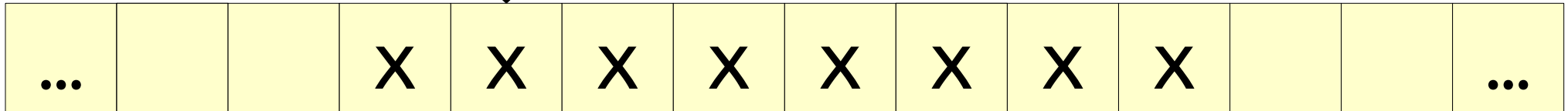
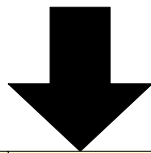
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Move Right

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

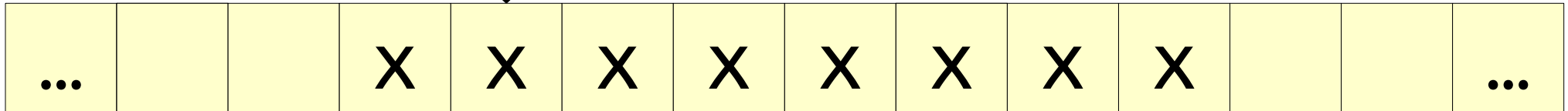
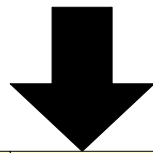
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

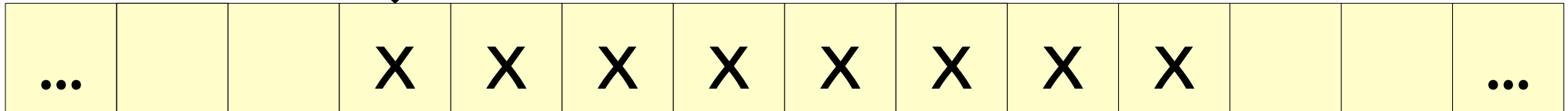
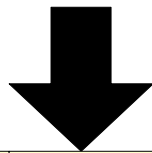
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

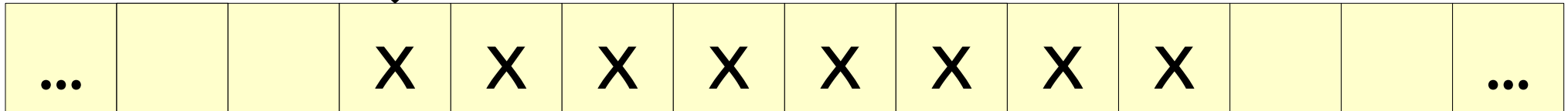
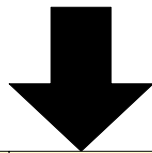
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

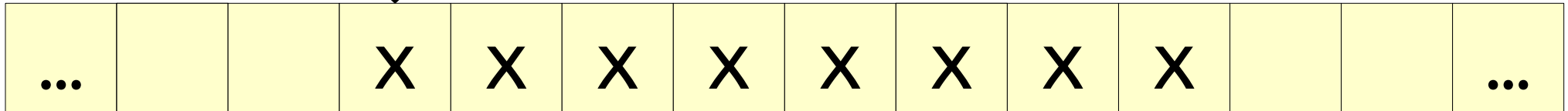
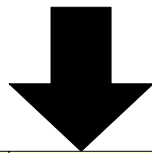
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

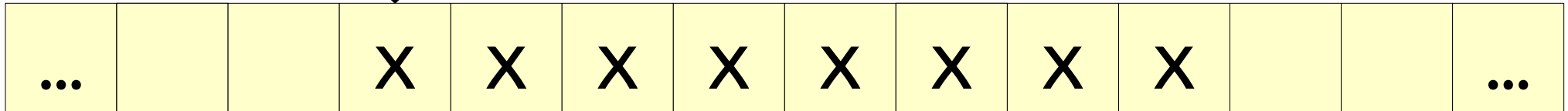
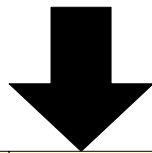
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Move Right

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

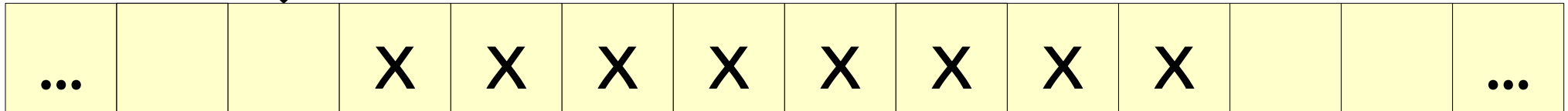
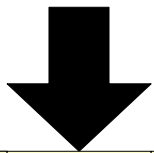
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

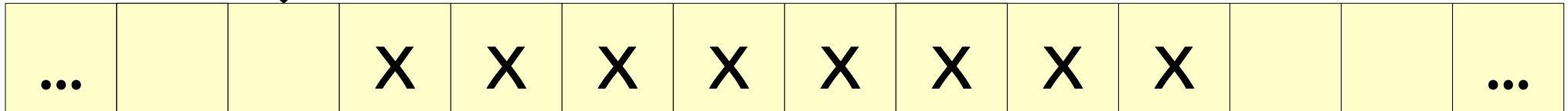
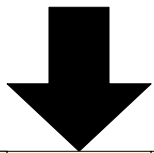
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

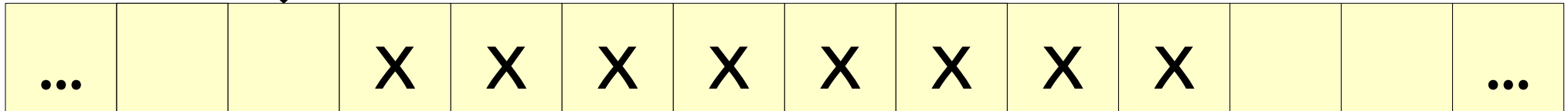
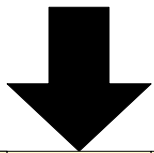
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

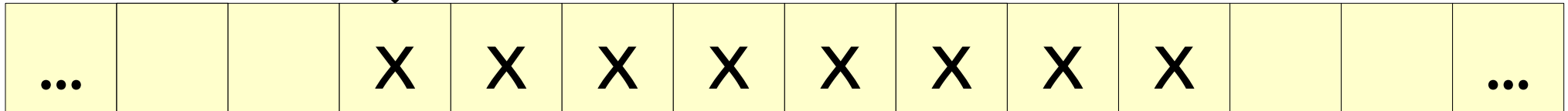
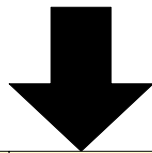
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

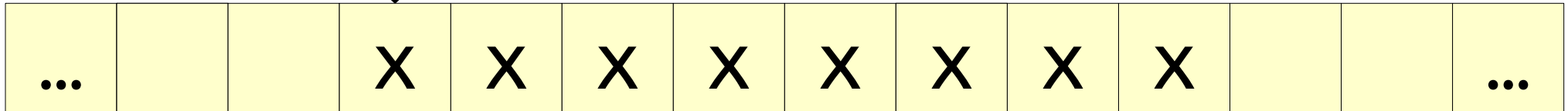
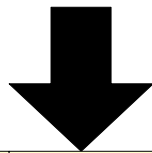
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

```
If 'a' Goto FoundA
If 'b' Goto FoundB
Move Right
Goto Start
```

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

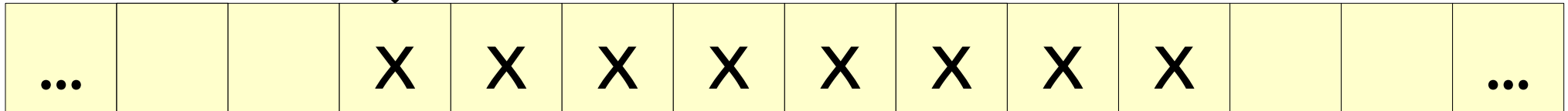
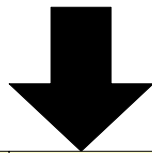
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

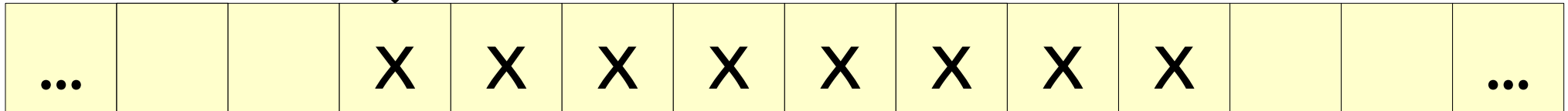
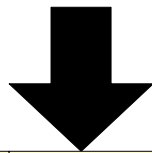
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'x' Goto LoopA

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

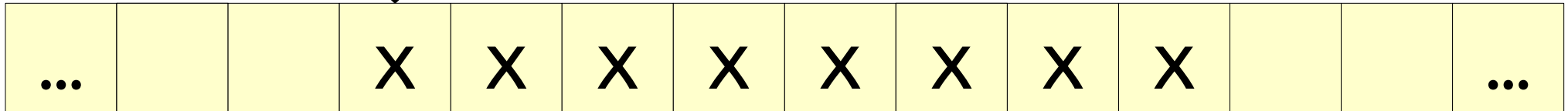
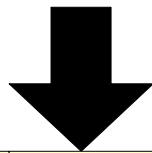
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

```
FoundA:
  Write 'x'
```

LoopA:

If 'a' Goto LoopA

Write 'x'

Goto GoHome

```
GoHome:
  Move Left
  If Not Blank Goto GoHome
  Move Right
  Goto Start
```

If Not Blank Goto GoHome

Goto Start

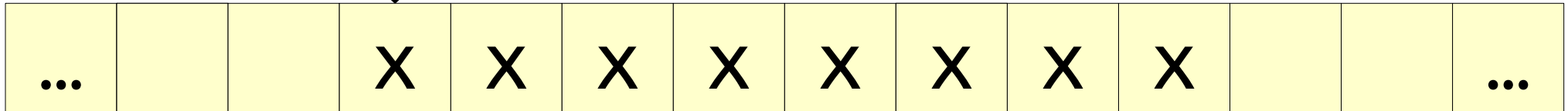
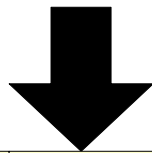
```
FoundB:
  Write 'x'
```

LoopB:

If 'b' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

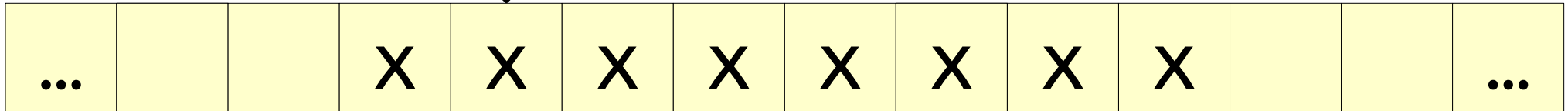
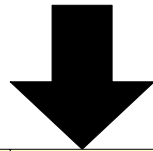
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
    Move Right
    Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'x' Goto LoopA

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

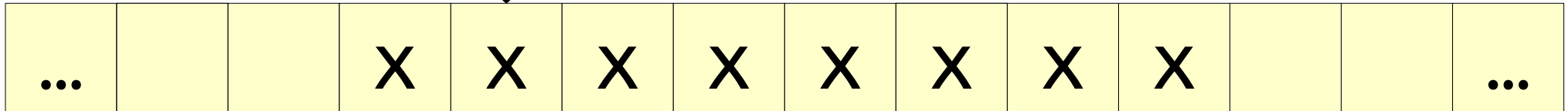
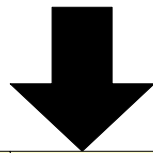
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

```
If 'a' Goto FoundA
If 'b' Goto FoundB
Move Right
Goto Start
```

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

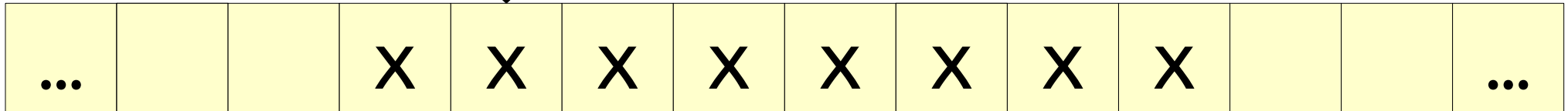
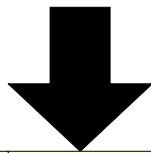
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

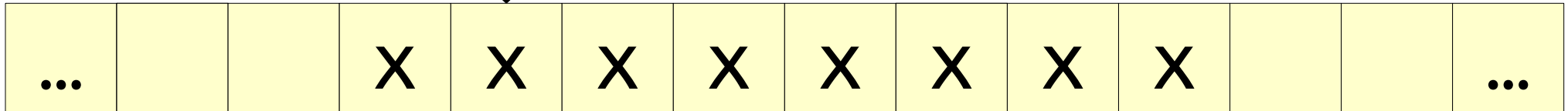
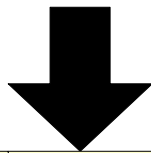
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

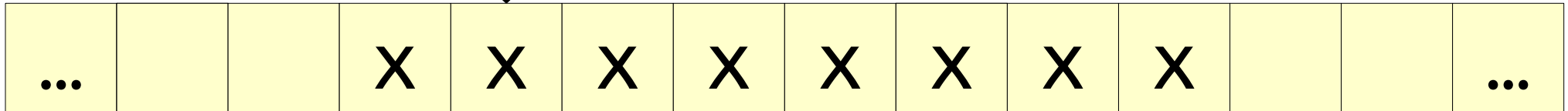
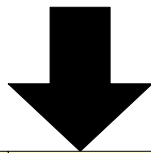
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

```
FoundA:
  Write 'x'
```

LoopA:

If 'a' Goto LoopA

If 'x' Goto LoopA

Goto GoHome

```
GoHome:
  Move Left
  If Not Blank Goto GoHome
  Move Right
  Goto Start
```

If Not Blank Goto GoHome

Goto Start

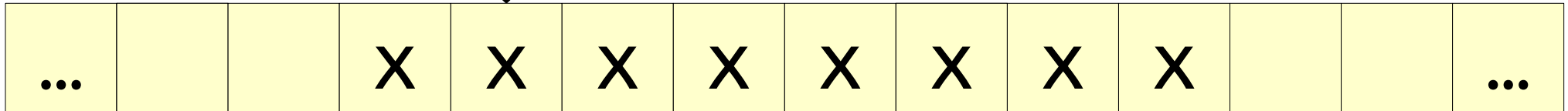
```
FoundB:
    Write 'x'
```

LoopB:

If 'b' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

```
FoundA:
  Write 'x'
```

LoopA:

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

```
GoHome:
  Move Left
  If Not Blank Goto GoHome
  Move Right
  Goto Start
```

If Not Blank Goto GoHome

Move Right

Goto Start

```
FoundB:
  Write 'x'
```

Write 'x'

LoopB:

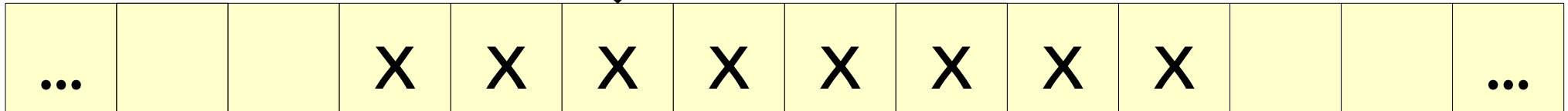
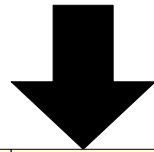
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
    Move Right
    Goto Start
```

If 'b' Goto FoundB

Goto Start

```
FoundA:
  Write 'x'
```

LoopA:

If 'a' Goto LoopA

Write 'x'

Goto GoHome

```
GoHome:
  Move Left
  If Not Blank Goto GoHome
  Move Right
  Goto Start
```

If Not Blank Goto GoHome

Goto Start

```
FoundB:
  Write 'x'
```

LoopB:

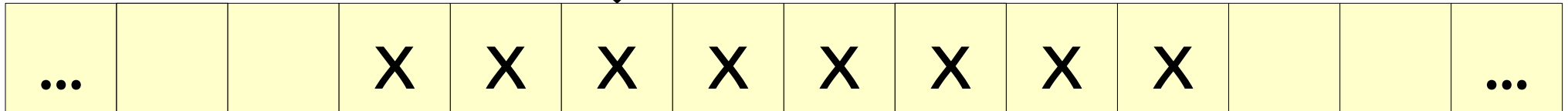
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

```
If 'a' Goto FoundA
If 'b' Goto FoundB
Move Right
Goto Start
```

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

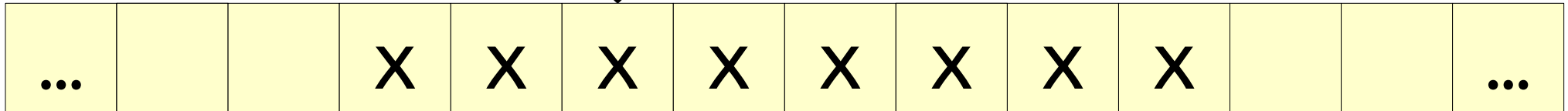
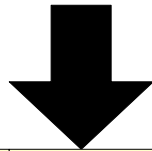
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

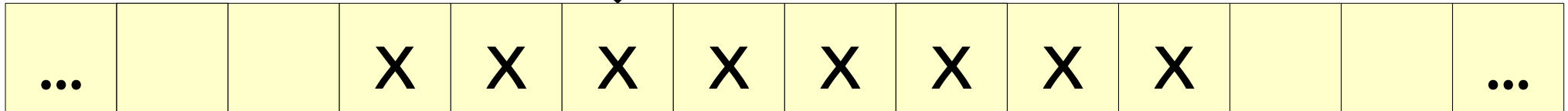
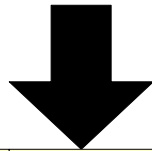
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'x' Goto LoopA

Goto GoHome

If Not Blank Goto GoHome

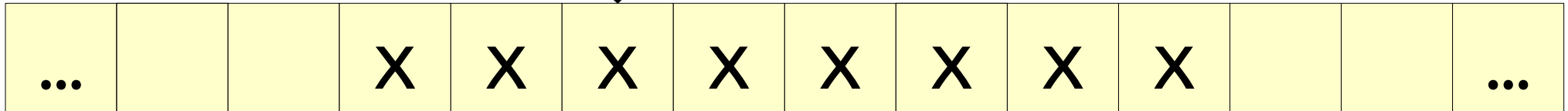
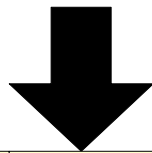
Goto Start

Write 'x'

Move Right

If 'x' Goto LoopB

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

```
FoundA:
  Write 'x'
```

LoopA:

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

```
GoHome:
  Move Left
  If Not Blank Goto GoHome
  Move Right
  Goto Start
```

If Not Blank Goto GoHome

Move Right

Goto Start

```
FoundB:
  Write 'x'
```

Write 'x'

LoopB:

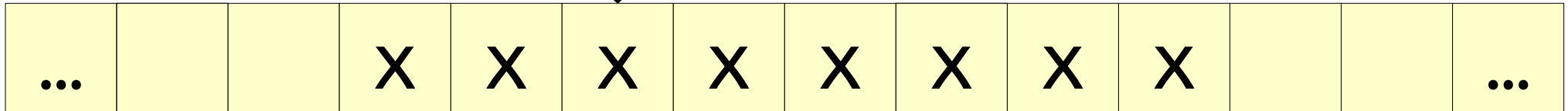
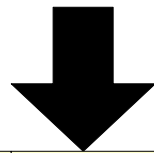
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

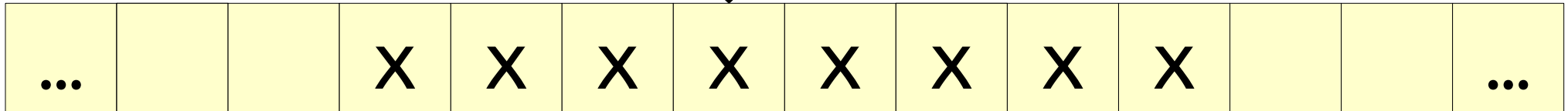
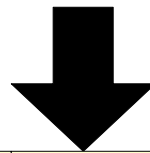
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
    Move Right
    Goto Start
```

If 'b' Goto FoundB

Goto Start

```
FoundA:
  Write 'x'
```

LoopA:

If 'a' Goto LoopA

Write 'x'

Goto GoHome

```
GoHome:
  Move Left
  If Not Blank Goto GoHome
  Move Right
  Goto Start
```

If Not Blank Goto GoHome

Goto Start

```
FoundB:
    Write 'x'
```

LoopB:

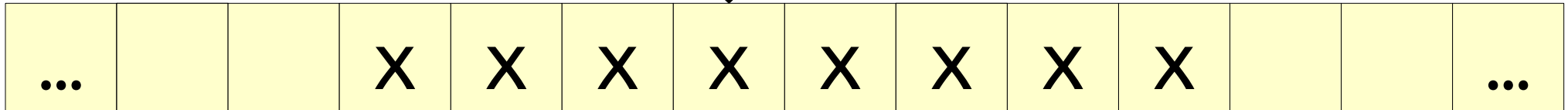
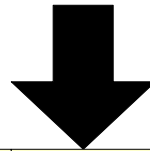
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

```
If 'a' Goto FoundA
If 'b' Goto FoundB
Move Right
Goto Start
```

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

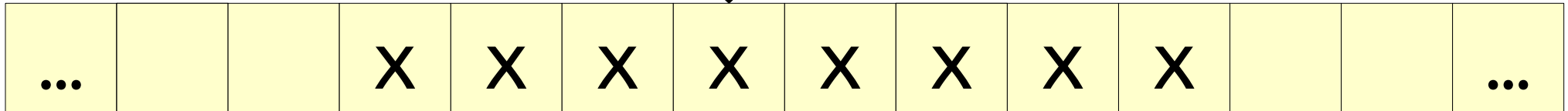
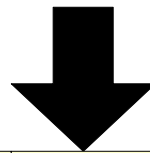
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

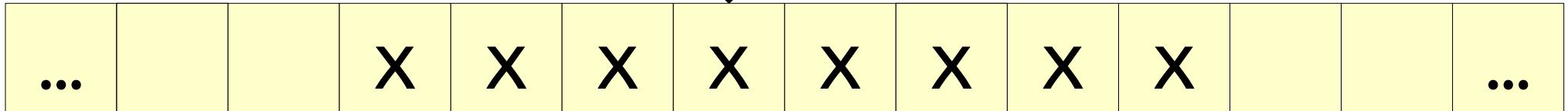
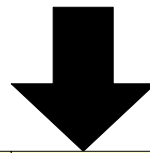
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

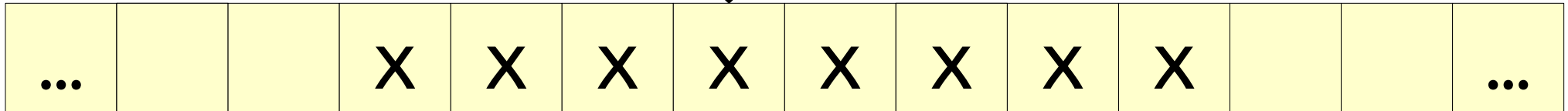
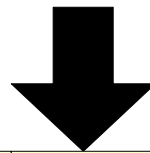
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

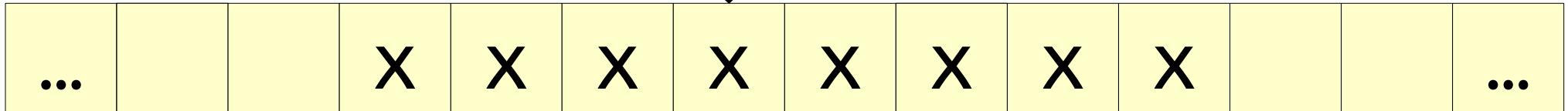
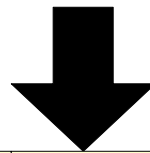
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

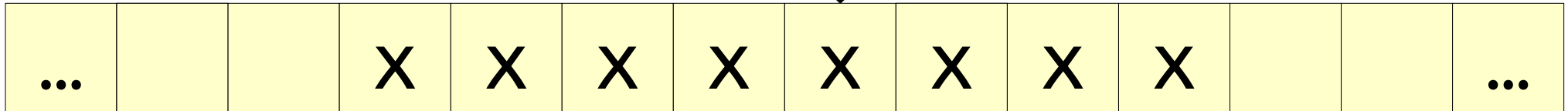
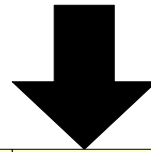
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
    Move Right
    Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'x' Goto LoopA

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

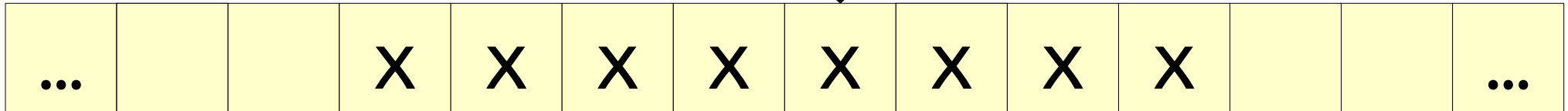
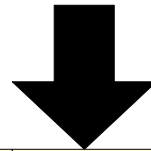
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

```
If 'a' Goto FoundA
If 'b' Goto FoundB
Move Right
Goto Start
```

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

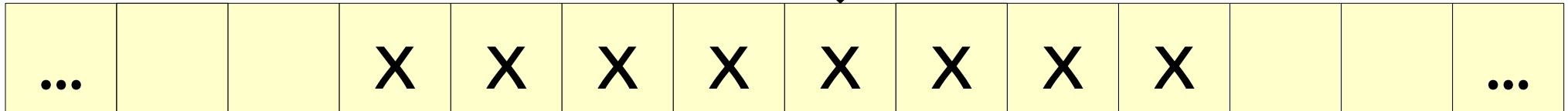
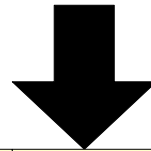
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

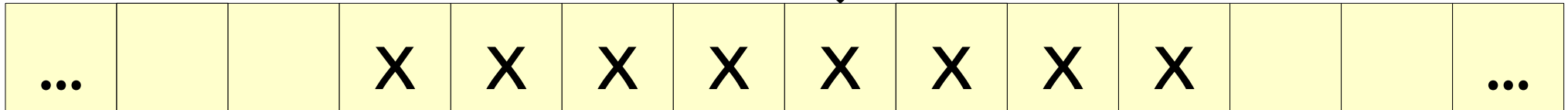
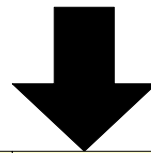
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'x' Goto LoopA

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

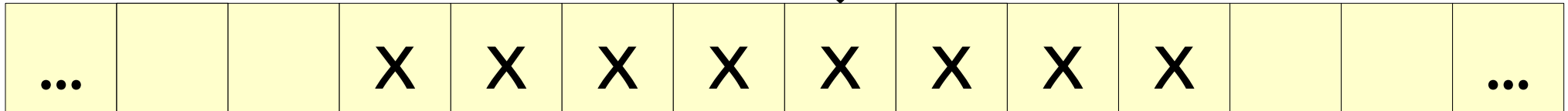
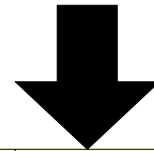
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

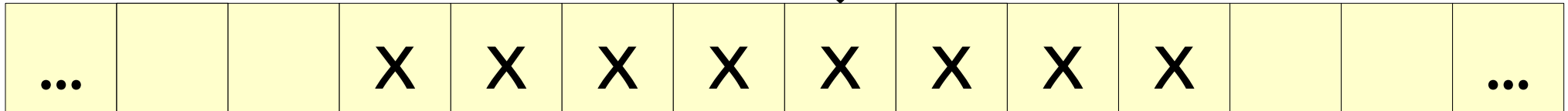
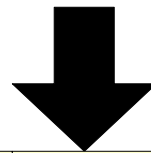
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

```
FoundA:
  Write 'x'
```

LoopA:

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

```
GoHome:
  Move Left
  If Not Blank Goto GoHome
  Move Right
  Goto Start
```

If Not Blank Goto GoHome

Goto Start

```
FoundB:
  Write 'x'
```

LoopB:

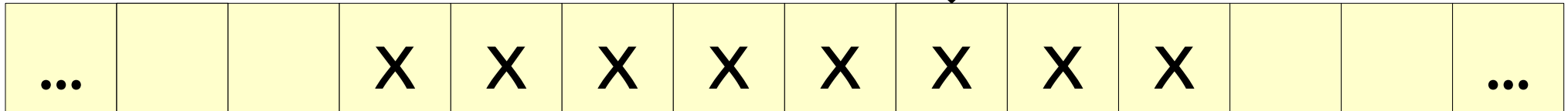
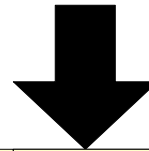
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
    Move Right
    Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

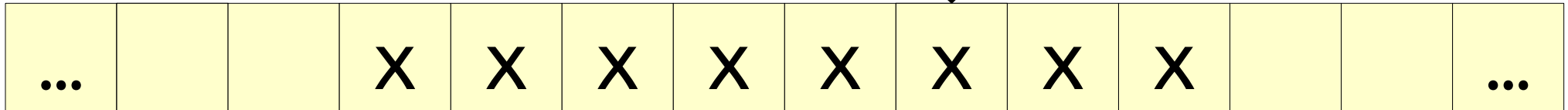
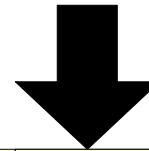
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

```
If 'a' Goto FoundA
If 'b' Goto FoundB
Move Right
Goto Start
```

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

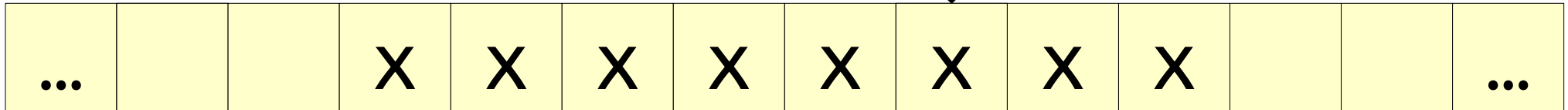
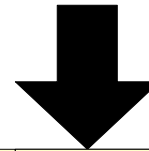
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

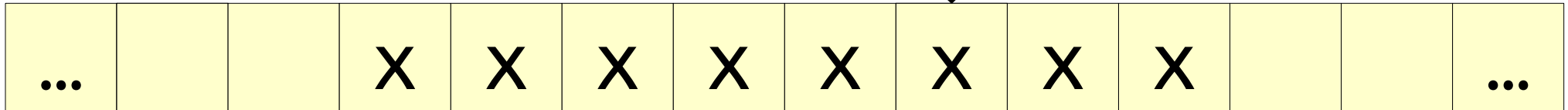
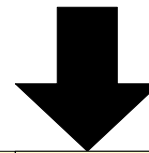
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

If Not Blank Goto GoHome

Goto Start

Write 'x'

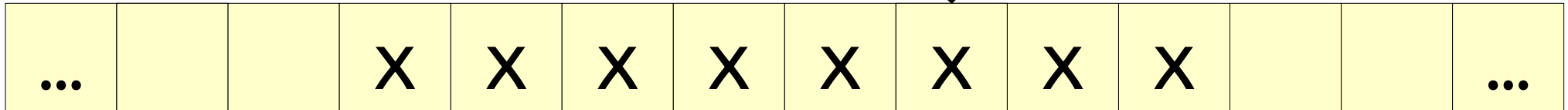
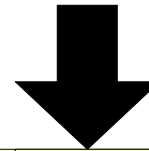
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

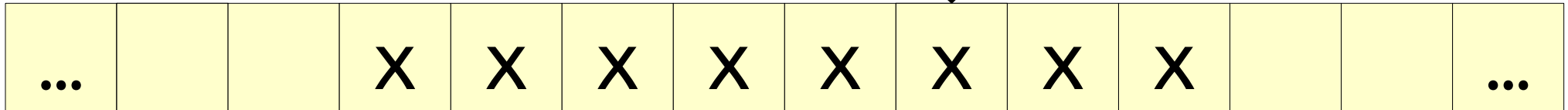
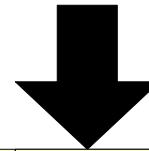
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

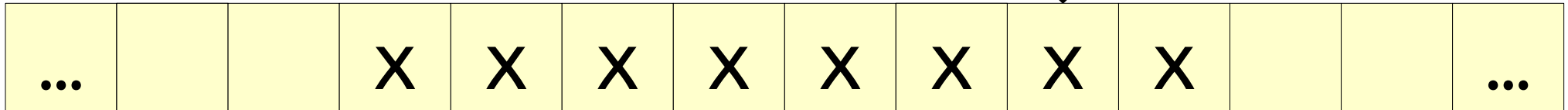
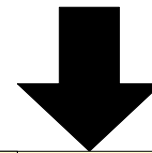
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
    Move Right
    Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'x' Goto LoopA

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

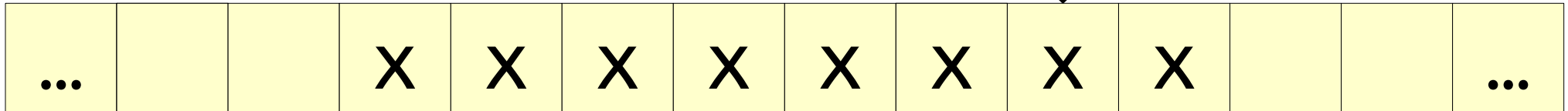
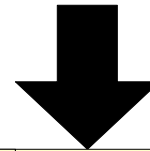
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

```
If 'a' Goto FoundA
If 'b' Goto FoundB
Move Right
Goto Start
```

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

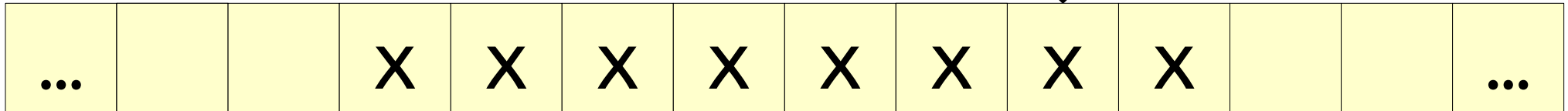
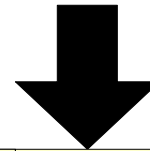
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

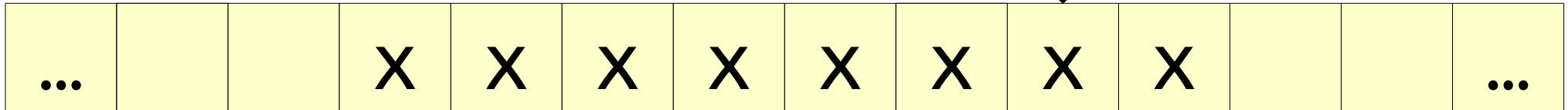
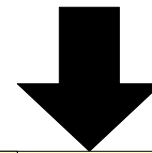
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

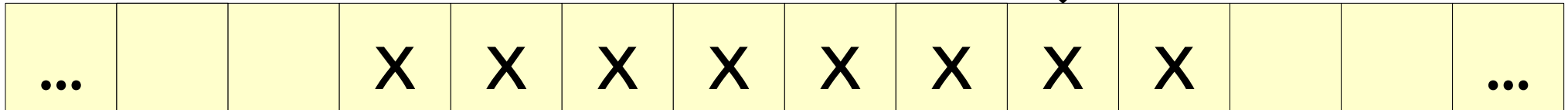
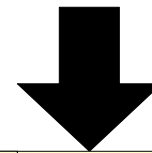
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

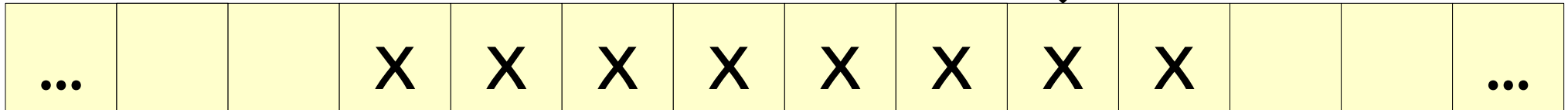
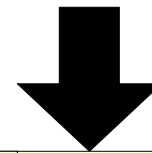
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

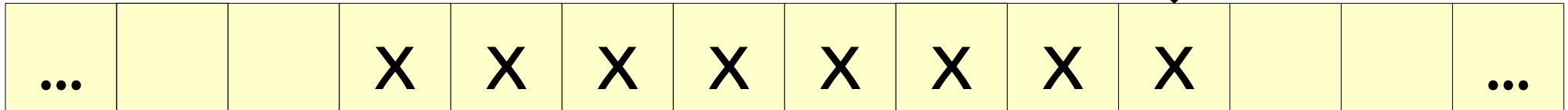
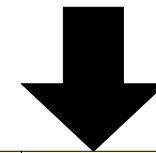
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
    Move Right
    Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'x' Goto LoopA

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

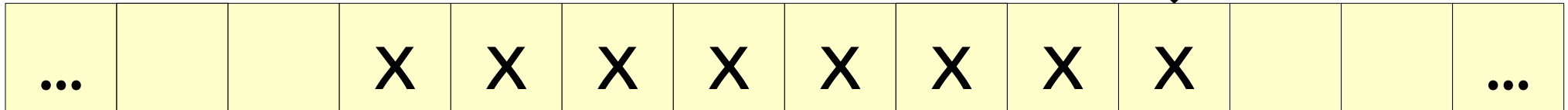
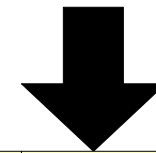
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

```
If 'a' Goto FoundA
If 'b' Goto FoundB
Move Right
Goto Start
```

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

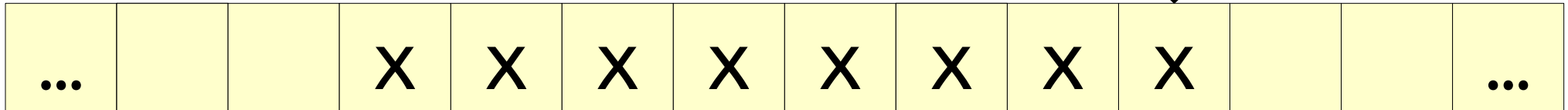
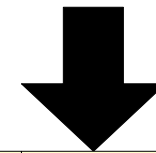
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

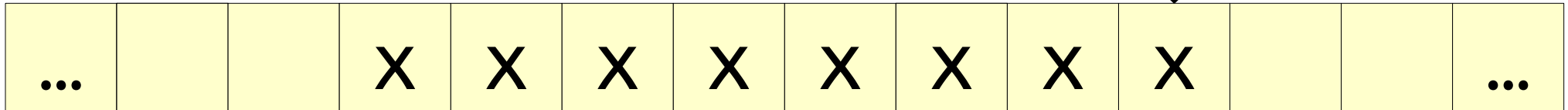
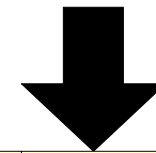
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

If Not Blank Goto GoHome

Goto Start

Write 'x'

LoopB:

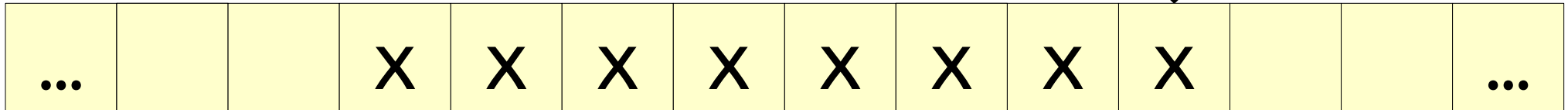
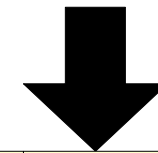
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

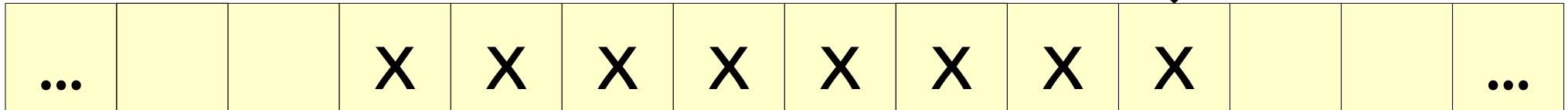
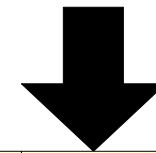
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

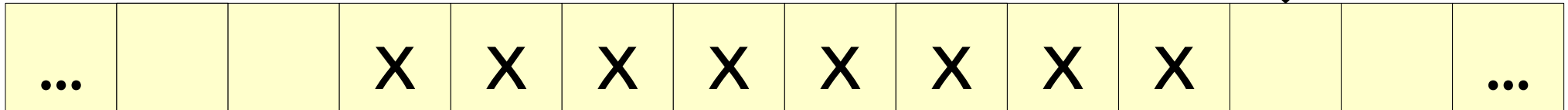
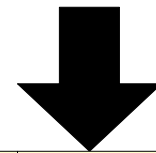
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
    Move Right
    Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'x' Goto LoopA

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

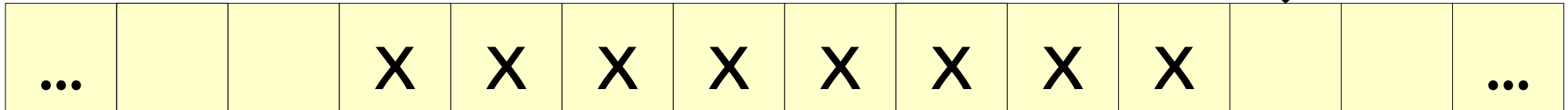
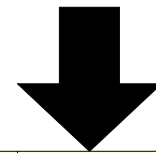
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

```
If 'a' Goto FoundA
If 'b' Goto FoundB
Move Right
Goto Start
```

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

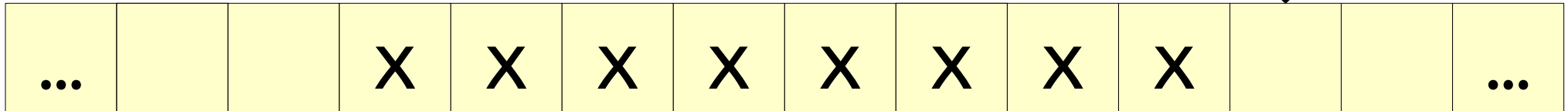
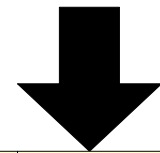
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

If 'a' Goto FoundA

If 'b' Goto FoundB

Move Right

Goto Start

FoundA:

Write 'x'

LoopA:

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

GoHome:

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

FoundB:

Write 'x'

LoopB:

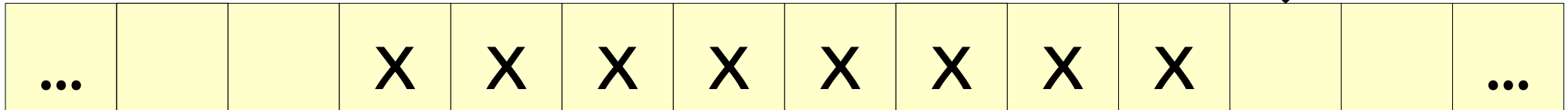
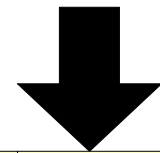
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
    If 'a' Goto FoundA
    If 'b' Goto FoundB
Move Right
Goto Start
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

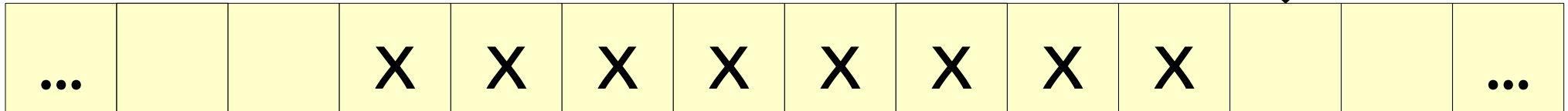
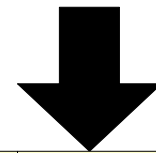
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
  If 'a' Goto FoundA
  If 'b' Goto FoundB
```

If 'b' Goto FoundB

Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

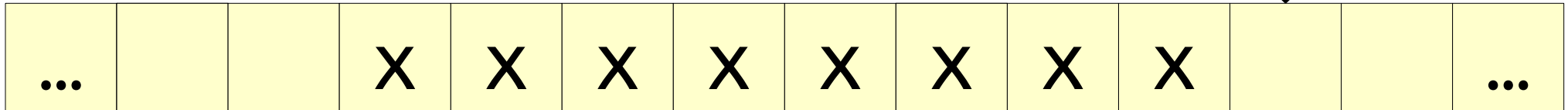
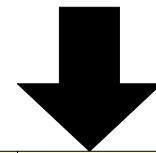
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
  If 'a' Goto FoundA
  If 'b' Goto FoundB
```

Move Right
Goto Start

Write 'x'

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

Write 'x'

LoopB:

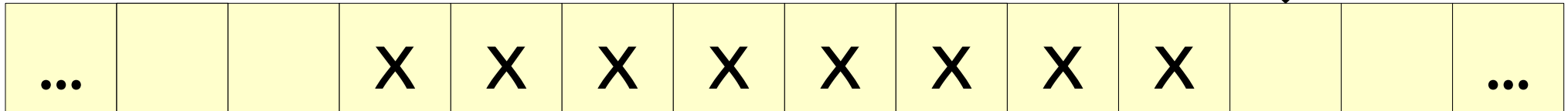
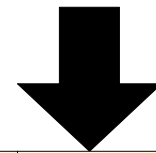
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
  If 'a' Goto FoundA
```

If 'b' Goto FoundB

If Blank Return True

Move Right

Goto Start

FoundA:
Write 'x'

Write 'x'

LoopA:
Move Right

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

```
GoHome:
    Move Left
```

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

```
FoundB:
    Write 'x'
```

Write 'x'

LoopB:
Move Right

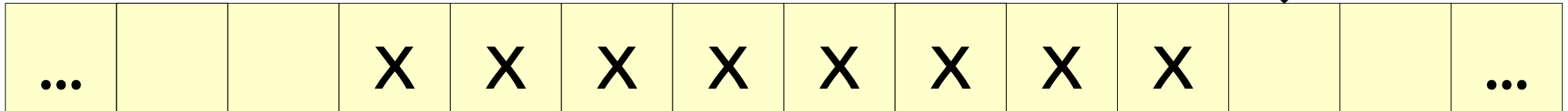
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



```
Start:
  If 'a' Goto FoundA
```

If 'b' Goto FoundB

If Blank Return True

Move Right

Goto Start

FoundA:
Write 'x'

Write 'x'

LoopA:
Move Right

Move Right

If 'a' Goto LoopA

If 'x' Goto LoopA

Write 'x'

Goto GoHome

```
GoHome:
    Move Left
```

Move Left

If Not Blank Goto GoHome

Move Right

Goto Start

```
FoundB:
  Write 'x'
```

Write 'x'

LoopB:
Move Right

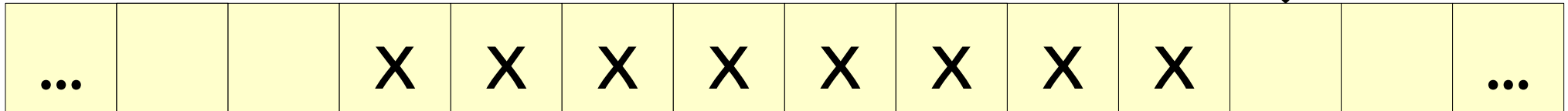
Move Right

If 'b' Goto LoopB

If 'x' Goto LoopB

Write 'x'

Goto GoHome



Start:

```
If 'a' Goto FoundA
If 'b' Goto FoundB
If Blank Return True
Move Right
Goto Start
```

FoundA:

```
Write 'x'
```

LoopA:

```
Move Right
If 'a' Goto LoopA
If 'x' Goto LoopA
Write 'x'
Goto GoHome
```

GoHome:

```
Move Left
If Not Blank Goto GoHome
Move Right
Goto Start
```

FoundB:

```
Write 'x'
```

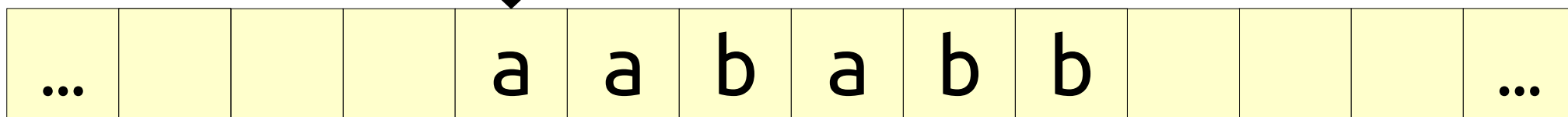
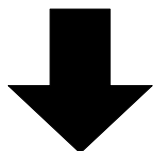
LoopB:

```
Move Right
If 'b' Goto LoopB
If 'x' Goto LoopB
Write 'x'
Goto GoHome
```

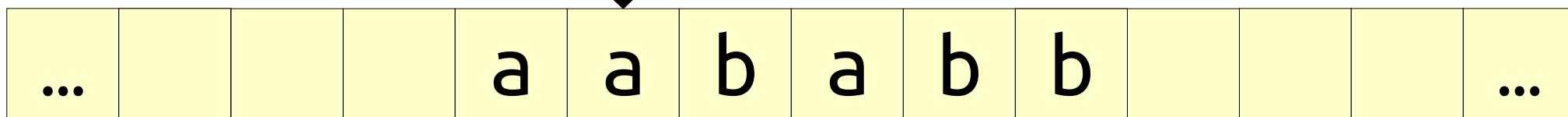
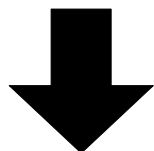

Another Idea

- We just built a TM for the language
$$\{ w \in \{\mathbf{a}, \mathbf{b}\}^* \mid w \text{ has the same number of } \mathbf{a}'\text{s and } \mathbf{b}'\text{s} \}.$$
- An observation: this would be a *lot* easier to test for if all the $\mathbf{a}$'s came before all the $\mathbf{b}$'s.
 - In fact, that would turn this into checking if the string has the form $\mathbf{a}^n \mathbf{b}^n$, which we already know how to do!
- **Idea:** Could we sort the characters of our input string?

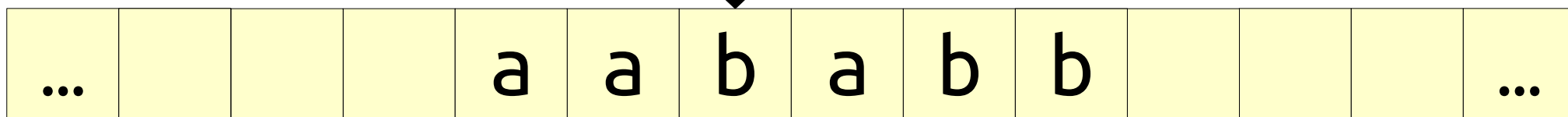
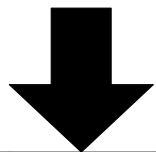
The Idea



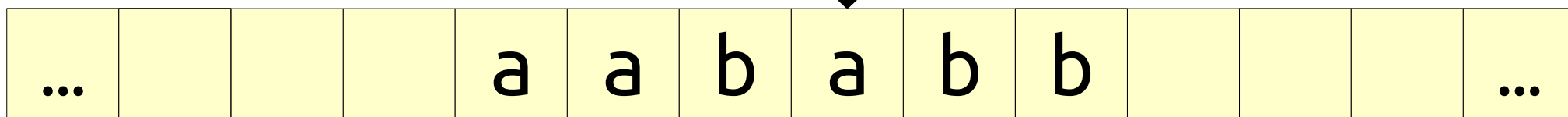
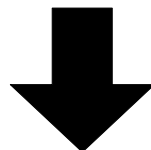
The Idea



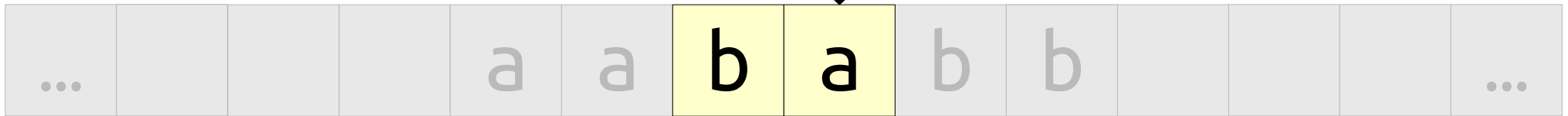
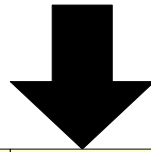
The Idea



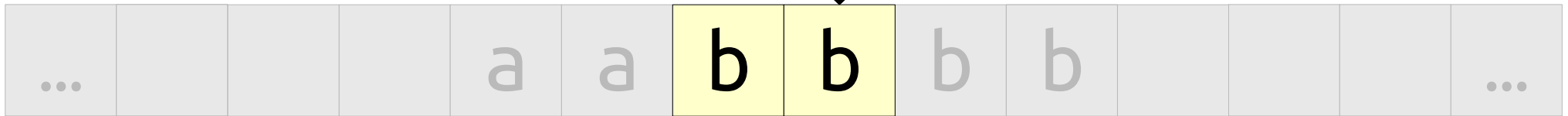
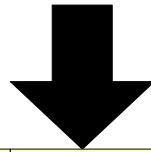
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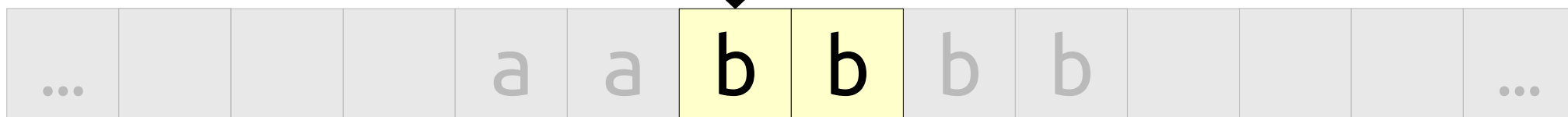
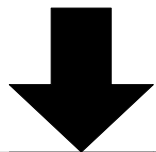
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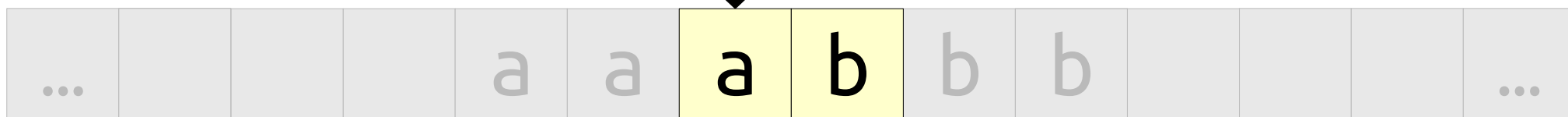
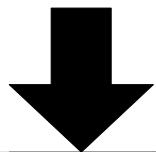
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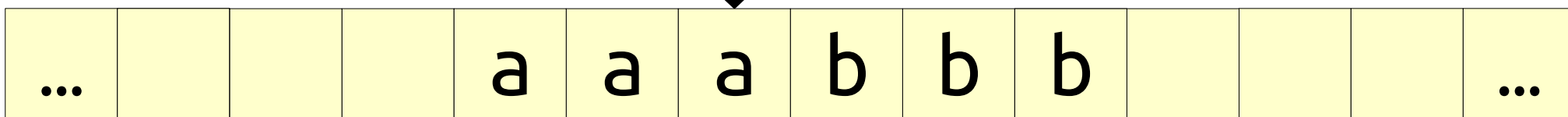
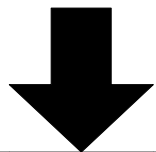
The Idea



The Idea



The Idea



Summary for Today

- Turing machines are abstract computers that issue commands to an infinite tape subdivided into cells.
- Each step of the TM can move the tape head, change what's on the tape, or jump to a different part of the program.
- TMs can be composed together to build larger TMs out of smaller ones.

Next Time

- ***The Church-Turing Thesis***
 - How powerful are Turing machines?
- ***Decidability and Recognizability***
 - Two notions of “solving a problem.”