

COSE 215: Theory of Computation

Lecture 18

Examples of Turing Machines (2)

Hakjoo Oh
2019 Spring

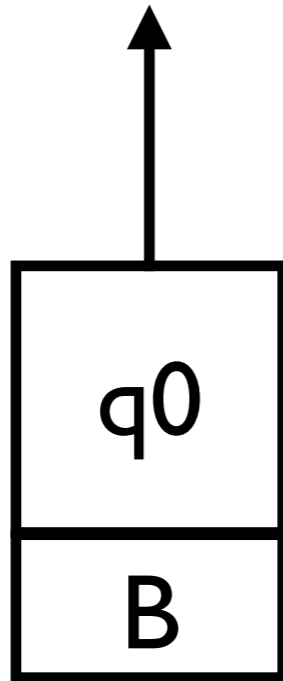
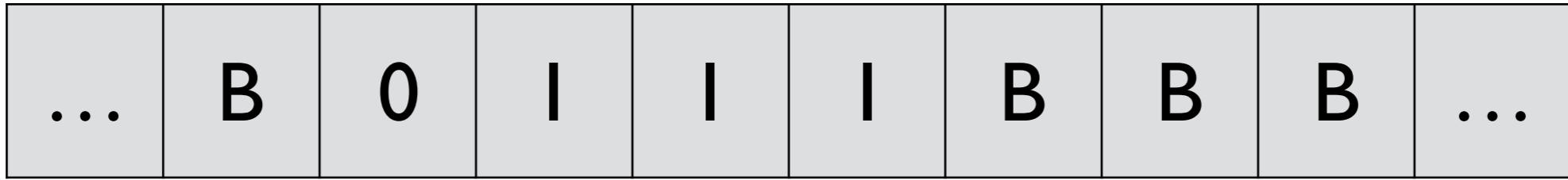
Example 1. Design a Turing machine that accepts $01^* + 10^*$.

$$M = (\{q_0, q_1\} \times \{0, 1, B\}, \{0, 1\}, \{0, 1, B\}, \delta, (q_0, B), B, \{(q_1, B)\})$$

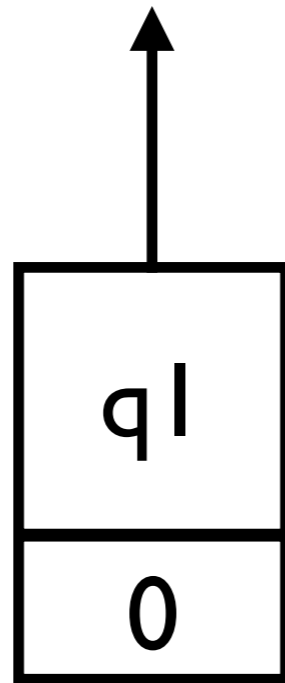
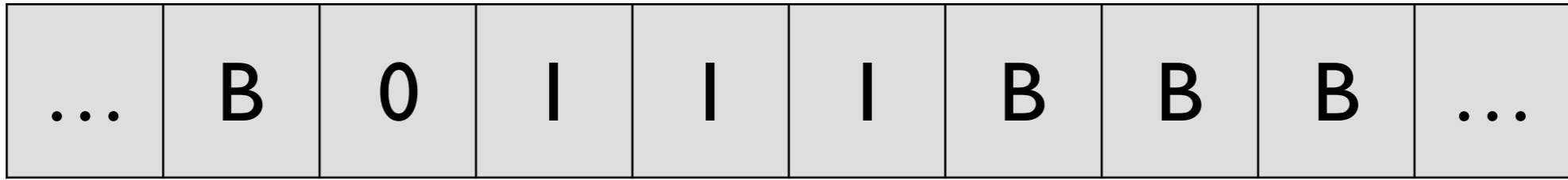
Example 1. Design a Turing machine that accepts $01^* + 10^*$.

$$M = (\{q_0, q_1\} \times \{0, 1, B\}, \{0, 1\}, \{0, 1, B\}, \delta, (q_0, B), B, \{(q_1, B)\})$$

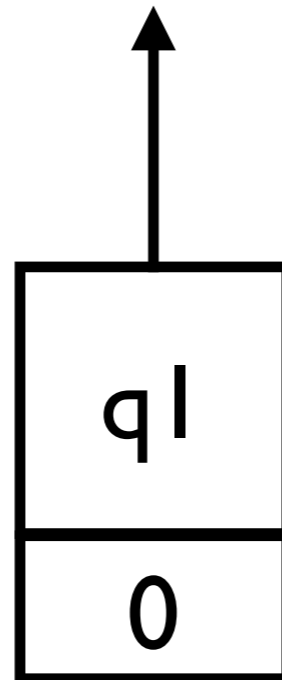
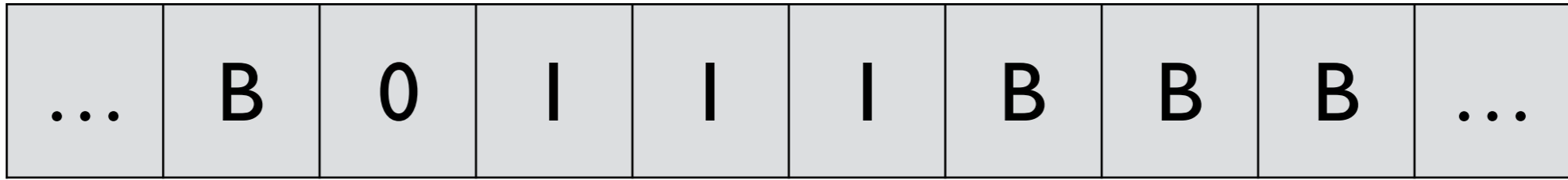
1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



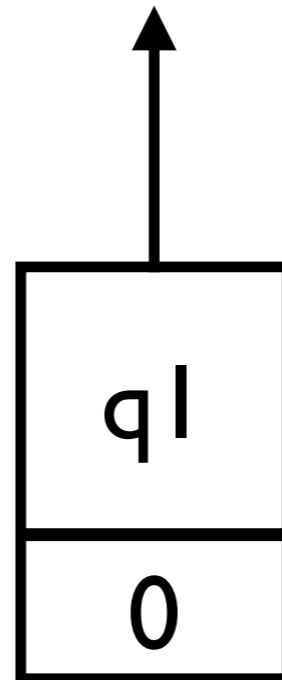
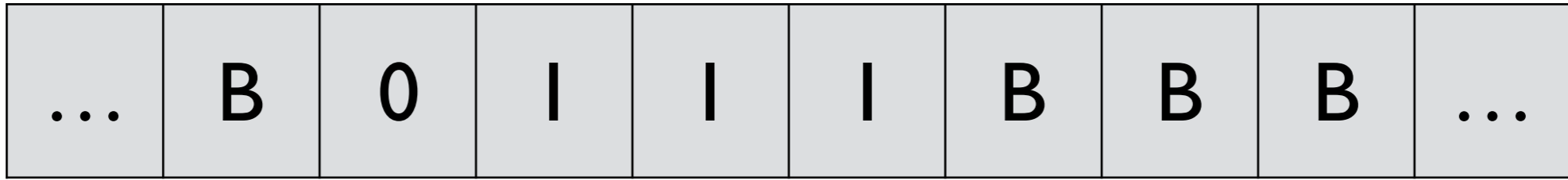
1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



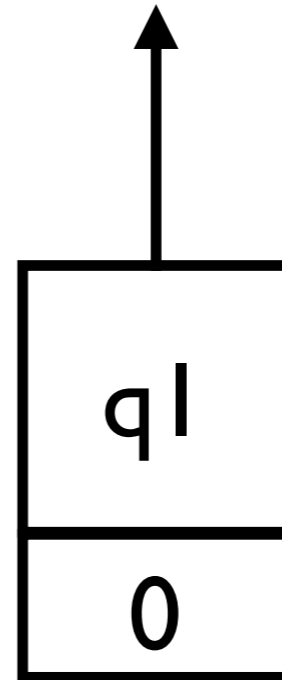
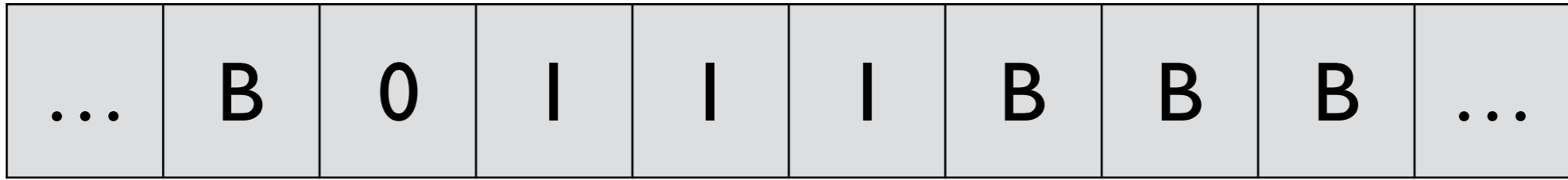
1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



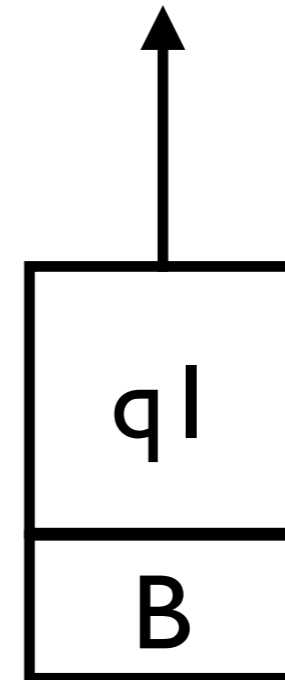
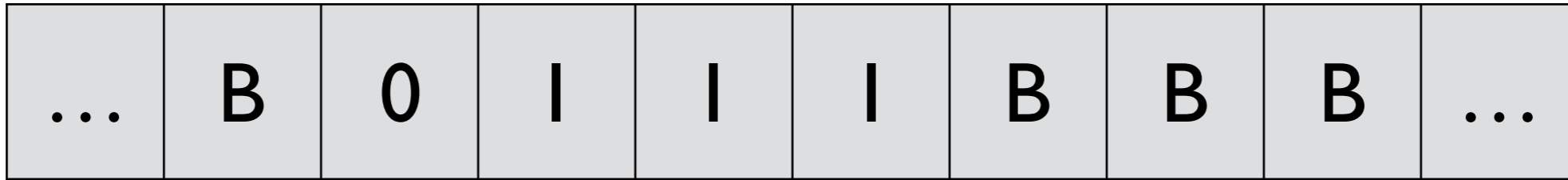
1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



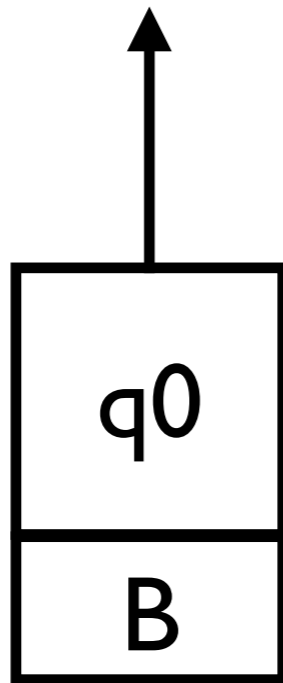
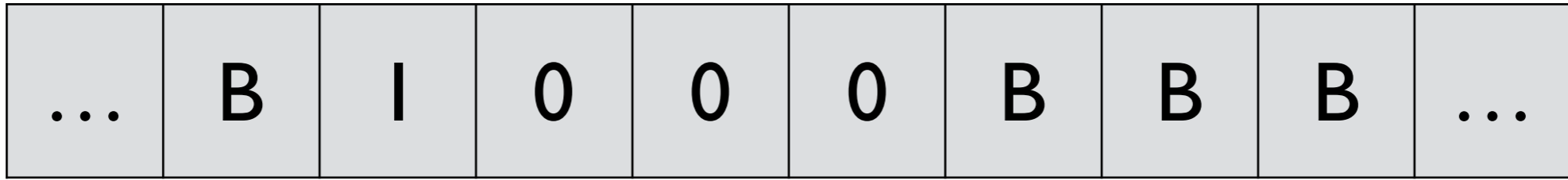
1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



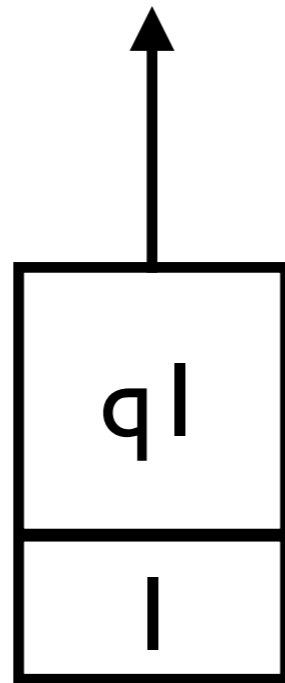
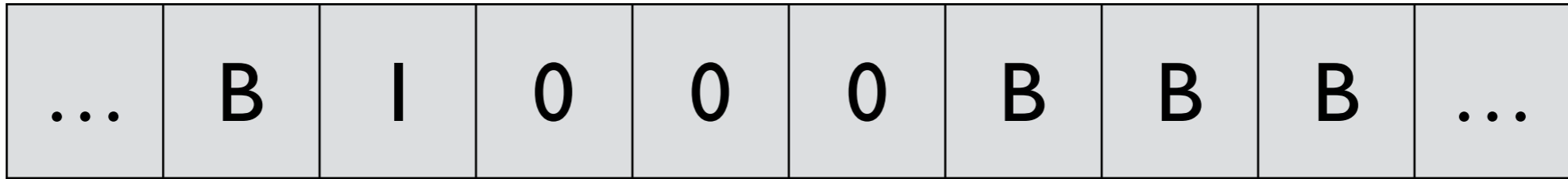
1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



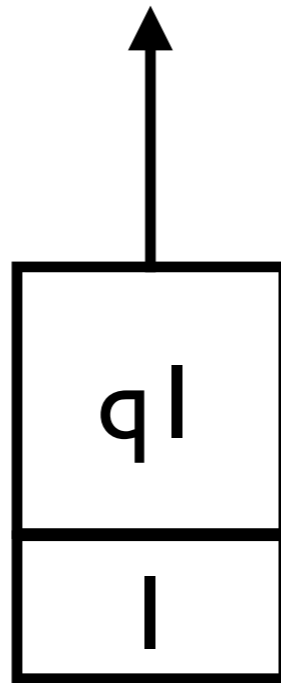
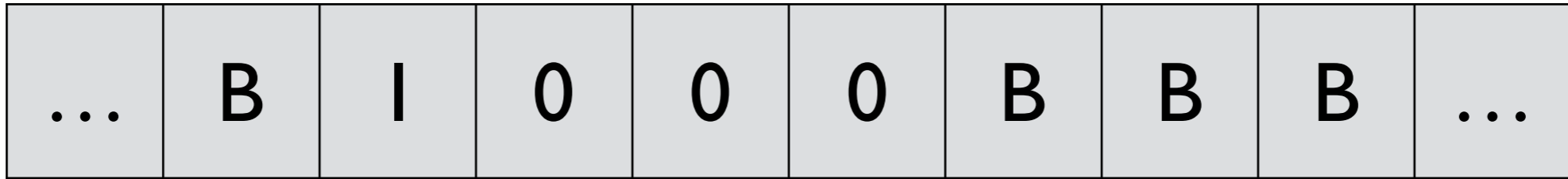
1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



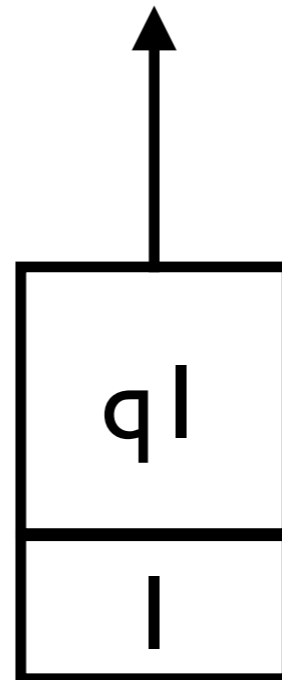
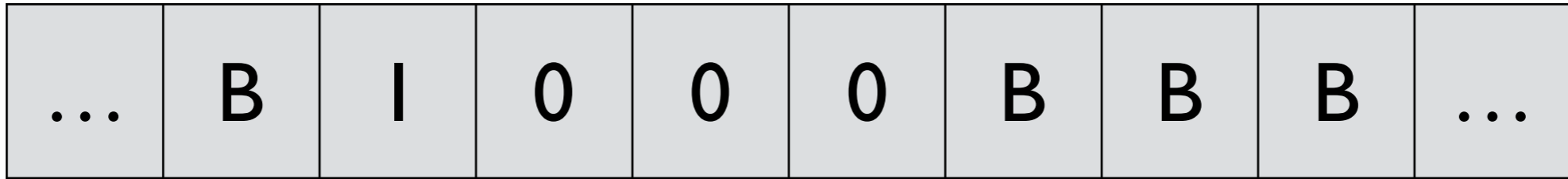
1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



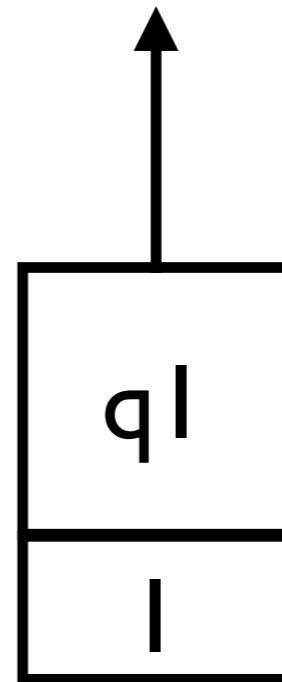
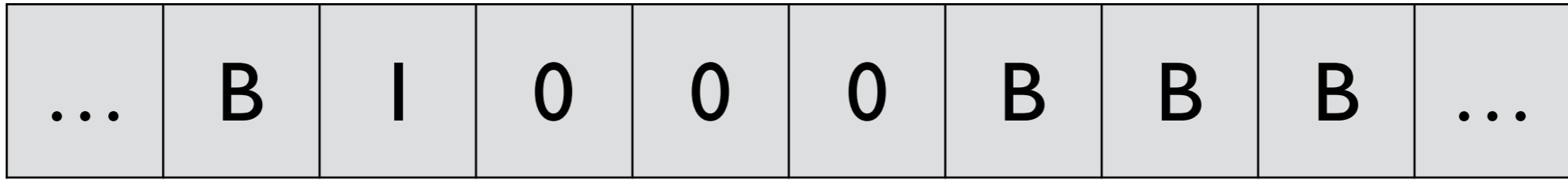
1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



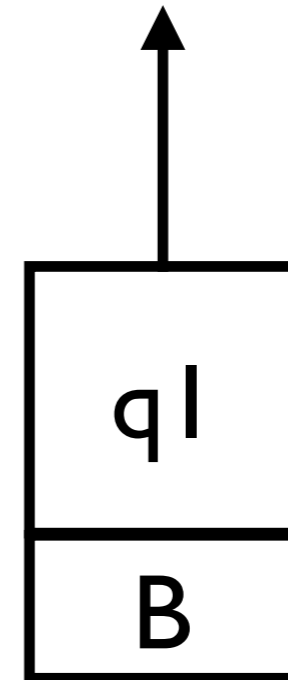
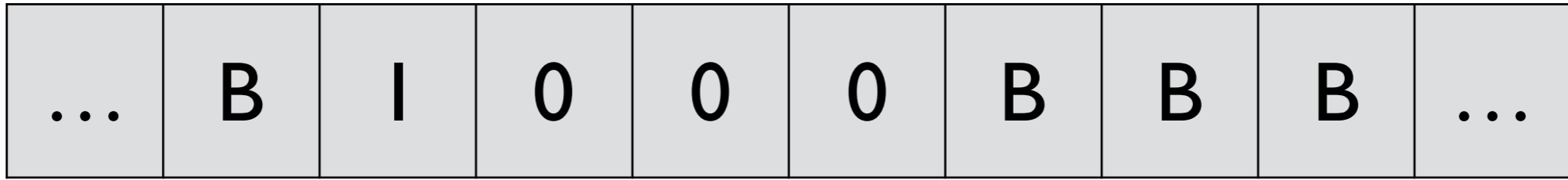
1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$



1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for $a = 0$ or $a = 1$
2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
3. $\delta((q_1, a), B) = ((q_1, B), B, R)$

Example 2. Design a Turing machine that accepts $L = \{w cw \mid w \in \{0, 1\}^+\}$.

Example 2. Design a Turing machine that accepts $L = \{w cw \mid w \in \{0, 1\}^+\}$.

$$M = (Q, \Sigma, \Gamma, \delta, (q_1, B), (B, B), \{q_9, B\})$$

- $\{q_1, q_2, \dots, q_9\} \times \{0, 1, B\}$
- $\Gamma = \{B, *\} \times \{0, 1, c, B\}$
- $\Sigma = \{(B, 0), (B, 1), (B, c)\}$

$$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$$

$$\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$$

$$\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$$

$$\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$$

$$\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$$

$$\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$$

$$\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$$

$$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$$

$$\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$$

$$\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$$

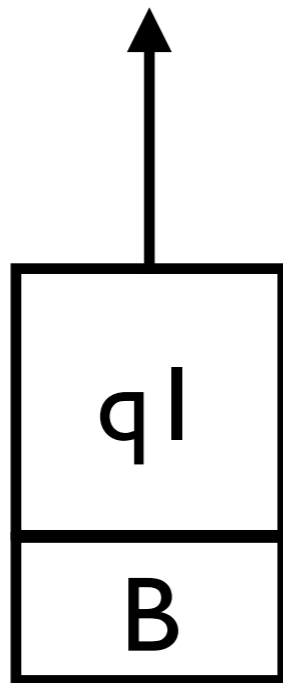
$$\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$$

$$\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$$

$$\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$$

$$\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$$

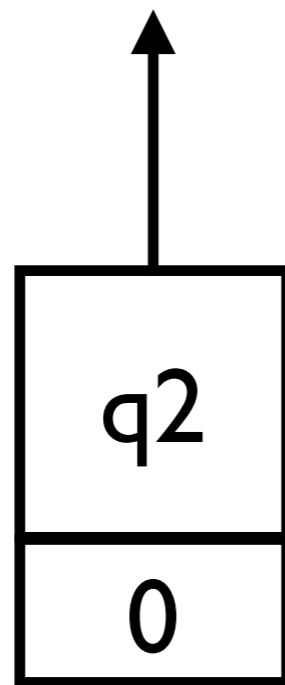
...	B	B	B	B	B	B	B	B	...
...	B	0	l	c	0	l	B	B	...



$$\begin{aligned}
\delta((q_1, B), (B, a)) &= ((q_2, a), (*, a), R) \\
\delta((q_2, a), (B, b)) &= ((q_2, a), (B, b), R) \\
\delta((q_2, a), (B, c)) &= ((q_3, a), (B, c), R) \\
\delta((q_3, a), (*, b)) &= ((q_3, a), (*, b), R) \\
\delta((q_3, a), (B, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (*, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (B, c)) &= ((q_5, B), (B, c), L)
\end{aligned}$$

$$\begin{aligned}
\delta((q_5, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (*, a)) &= ((q_1, B), (*, a), R) \\
\delta((q_5, B), (*, a)) &= ((q_7, B), (*, a), R) \\
\delta((q_7, B), (B, c)) &= ((q_8, B), (B, c), R) \\
\delta((q_8, B), (*, a)) &= ((q_8, B), (*, a), R) \\
\delta((q_8, B), (B, B)) &= ((q_9, B), (B, B), R)
\end{aligned}$$

...	B	*	B	B	B	B	B	B	...
...	B	0	I	c	0	I	B	B	...

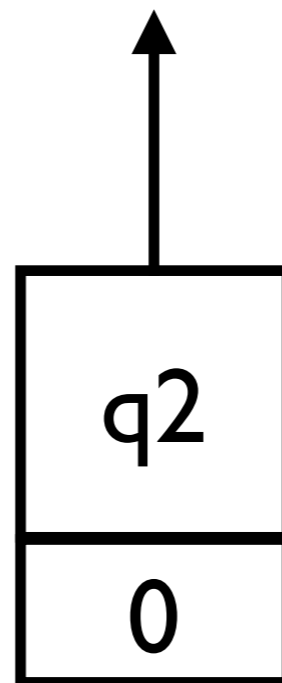


In q_2 , moves right, looking for c

$$\begin{aligned} \delta((q_1, B), (B, a)) &= ((q_2, a), (*, a), R) \\ \delta((q_2, a), (B, b)) &= ((q_2, a), (B, b), R) \\ \delta((q_2, a), (B, c)) &= ((q_3, a), (B, c), R) \\ \delta((q_3, a), (*, b)) &= ((q_3, a), (*, b), R) \\ \delta((q_3, a), (B, a)) &= ((q_4, B), (*, a), L) \\ \delta((q_4, B), (*, a)) &= ((q_4, B), (*, a), L) \\ \delta((q_4, B), (B, c)) &= ((q_5, B), (B, c), L) \end{aligned}$$

$$\begin{aligned} \delta((q_5, B), (B, a)) &= ((q_6, B), (B, a), L) \\ \delta((q_6, B), (B, a)) &= ((q_6, B), (B, a), L) \\ \delta((q_6, B), (*, a)) &= ((q_1, B), (*, a), R) \\ \delta((q_5, B), (*, a)) &= ((q_7, B), (*, a), R) \\ \delta((q_7, B), (B, c)) &= ((q_8, B), (B, c), R) \\ \delta((q_8, B), (*, a)) &= ((q_8, B), (*, a), R) \\ \delta((q_8, B), (B, B)) &= ((q_9, B), (B, B), R) \end{aligned}$$

...	B	*	B	B	B	B	B	B	...
...	B	0	l	c	0	l	B	B	...

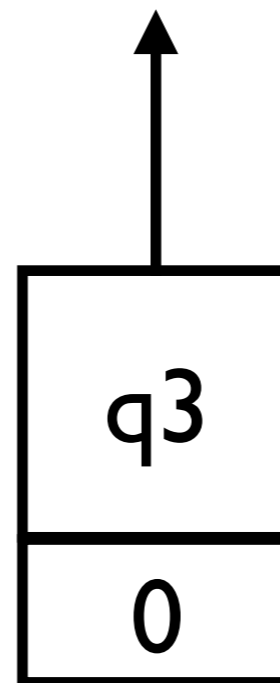


- When found,
- enter q3
 - continue right

$$\begin{aligned}
\delta((q_1, B), (B, a)) &= ((q_2, a), (*, a), R) \\
\delta((q_2, a), (B, b)) &= ((q_2, a), (B, b), R) \\
\delta((q_2, a), (B, c)) &= ((q_3, a), (B, c), R) \\
\delta((q_3, a), (*, b)) &= ((q_3, a), (*, b), R) \\
\delta((q_3, a), (B, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (*, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (B, c)) &= ((q_5, B), (B, c), L)
\end{aligned}$$

$$\begin{aligned}
\delta((q_5, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (*, a)) &= ((q_1, B), (*, a), R) \\
\delta((q_5, B), (*, a)) &= ((q_7, B), (*, a), R) \\
\delta((q_7, B), (B, c)) &= ((q_8, B), (B, c), R) \\
\delta((q_8, B), (*, a)) &= ((q_8, B), (*, a), R) \\
\delta((q_8, B), (B, B)) &= ((q_9, B), (B, B), R)
\end{aligned}$$

...	B	*	B	B	B	B	B	B	...
...	B	0	l	c	0	l	B	B	...

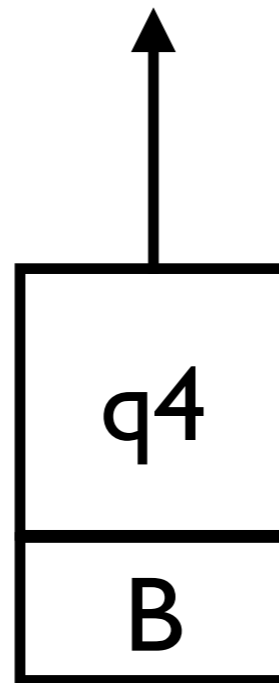


In q_3 ,
look for the first
unchecked symbol

$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$
 $\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$
 $\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$
 $\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$
 $\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$

$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$
 $\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$
 $\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$
 $\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$
 $\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$

...	B	*	B	B	*	B	B	B	...
...	B	0	l	c	0	l	B	B	...

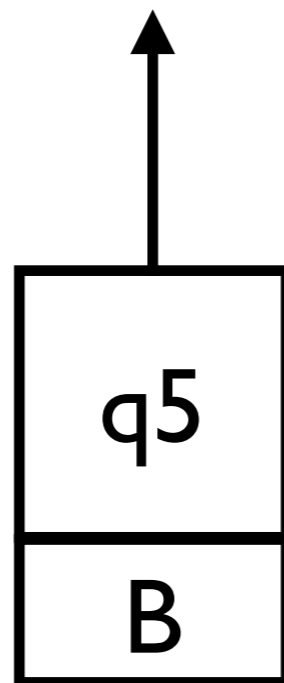


- In q_4 , move left until it finds c
- When found, enter q_5

$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$
 $\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$
 $\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$
 $\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$
 $\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$

$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$
 $\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$
 $\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$
 $\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$
 $\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$

...	B	*	B	B	*	B	B	B	...
...	B	0	l	c	0	l	B	B	...

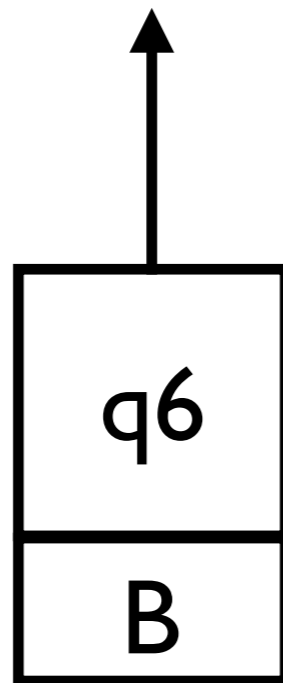


- If there is some unchecked symbol, enter q6

$$\begin{aligned} \delta((q_1, B), (B, a)) &= ((q_2, a), (*, a), R) \\ \delta((q_2, a), (B, b)) &= ((q_2, a), (B, b), R) \\ \delta((q_2, a), (B, c)) &= ((q_3, a), (B, c), R) \\ \delta((q_3, a), (*, b)) &= ((q_3, a), (*, b), R) \\ \delta((q_3, a), (B, a)) &= ((q_4, B), (*, a), L) \\ \delta((q_4, B), (*, a)) &= ((q_4, B), (*, a), L) \\ \delta((q_4, B), (B, c)) &= ((q_5, B), (B, c), L) \end{aligned}$$

$$\begin{aligned} \delta((q_5, B), (B, a)) &= ((q_6, B), (B, a), L) \\ \delta((q_6, B), (B, a)) &= ((q_6, B), (B, a), L) \\ \delta((q_6, B), (*, a)) &= ((q_1, B), (*, a), R) \\ \delta((q_5, B), (*, a)) &= ((q_7, B), (*, a), R) \\ \delta((q_7, B), (B, c)) &= ((q_8, B), (B, c), R) \\ \delta((q_8, B), (*, a)) &= ((q_8, B), (*, a), R) \\ \delta((q_8, B), (B, B)) &= ((q_9, B), (B, B), R) \end{aligned}$$

...	B	*	B	B	*	B	B	B	...
...	B	0	l	c	0	l	B	B	...

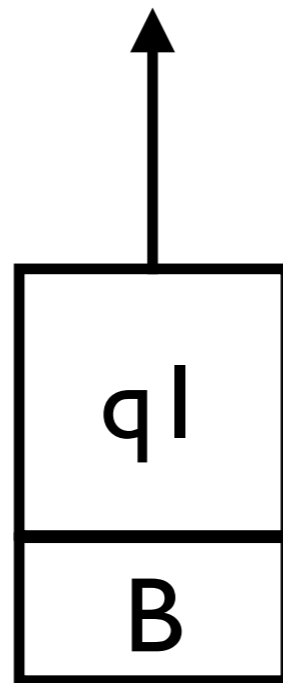


- In q6, move left and look for the first checked symbol

$$\begin{aligned} \delta((q_1, B), (B, a)) &= ((q_2, a), (*, a), R) \\ \delta((q_2, a), (B, b)) &= ((q_2, a), (B, b), R) \\ \delta((q_2, a), (B, c)) &= ((q_3, a), (B, c), R) \\ \delta((q_3, a), (*, b)) &= ((q_3, a), (*, b), R) \\ \delta((q_3, a), (B, a)) &= ((q_4, B), (*, a), L) \\ \delta((q_4, B), (*, a)) &= ((q_4, B), (*, a), L) \\ \delta((q_4, B), (B, c)) &= ((q_5, B), (B, c), L) \end{aligned}$$

$$\begin{aligned} \delta((q_5, B), (B, a)) &= ((q_6, B), (B, a), L) \\ \delta((q_6, B), (B, a)) &= ((q_6, B), (B, a), L) \\ \delta((q_6, B), (*, a)) &= ((q_1, B), (*, a), R) \\ \delta((q_5, B), (*, a)) &= ((q_7, B), (*, a), R) \\ \delta((q_7, B), (B, c)) &= ((q_8, B), (B, c), R) \\ \delta((q_8, B), (*, a)) &= ((q_8, B), (*, a), R) \\ \delta((q_8, B), (B, B)) &= ((q_9, B), (B, B), R) \end{aligned}$$

...	B	*	B	B	*	B	B	B	...
...	B	0	l	c	0	l	B	B	...

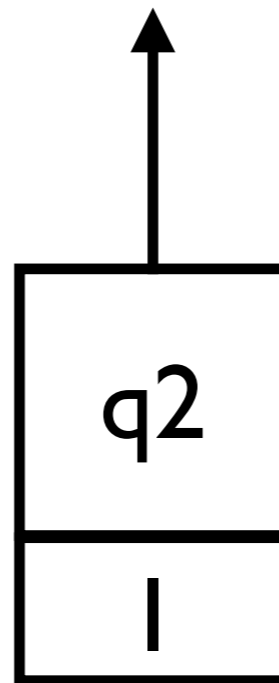


- Repeat the cycle

$$\begin{aligned}
\delta((q_1, B), (B, a)) &= ((q_2, a), (*, a), R) \\
\delta((q_2, a), (B, b)) &= ((q_2, a), (B, b), R) \\
\delta((q_2, a), (B, c)) &= ((q_3, a), (B, c), R) \\
\delta((q_3, a), (*, b)) &= ((q_3, a), (*, b), R) \\
\delta((q_3, a), (B, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (*, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (B, c)) &= ((q_5, B), (B, c), L)
\end{aligned}$$

$$\begin{aligned}
\delta((q_5, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (*, a)) &= ((q_1, B), (*, a), R) \\
\delta((q_5, B), (*, a)) &= ((q_7, B), (*, a), R) \\
\delta((q_7, B), (B, c)) &= ((q_8, B), (B, c), R) \\
\delta((q_8, B), (*, a)) &= ((q_8, B), (*, a), R) \\
\delta((q_8, B), (B, B)) &= ((q_9, B), (B, B), R)
\end{aligned}$$

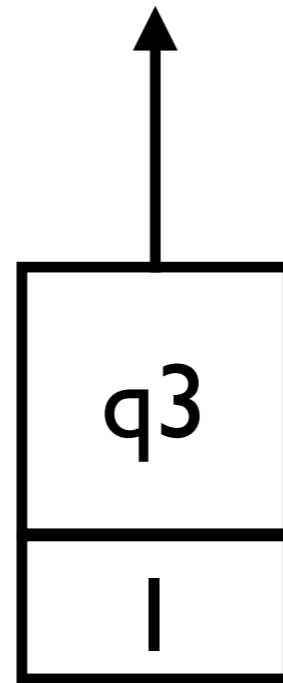
...	B	*	*	B	*	B	B	B	...
...	B	0	l	c	0	l	B	B	...



$$\begin{aligned}
\delta((q_1, B), (B, a)) &= ((q_2, a), (*, a), R) \\
\delta((q_2, a), (B, b)) &= ((q_2, a), (B, b), R) \\
\delta((q_2, a), (B, c)) &= ((q_3, a), (B, c), R) \\
\delta((q_3, a), (*, b)) &= ((q_3, a), (*, b), R) \\
\delta((q_3, a), (B, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (*, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (B, c)) &= ((q_5, B), (B, c), L)
\end{aligned}$$

$$\begin{aligned}
\delta((q_5, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (*, a)) &= ((q_1, B), (*, a), R) \\
\delta((q_5, B), (*, a)) &= ((q_7, B), (*, a), R) \\
\delta((q_7, B), (B, c)) &= ((q_8, B), (B, c), R) \\
\delta((q_8, B), (*, a)) &= ((q_8, B), (*, a), R) \\
\delta((q_8, B), (B, B)) &= ((q_9, B), (B, B), R)
\end{aligned}$$

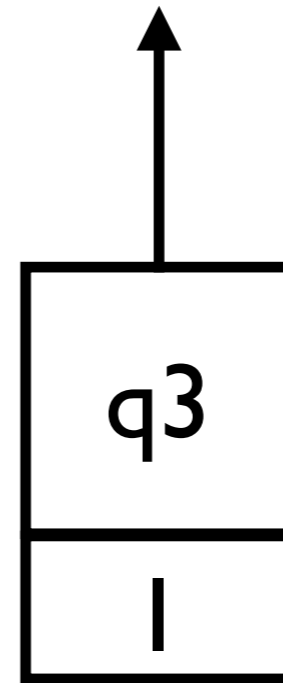
...	B	*	*	B	*	B	B	B	...
...	B	0	l	c	0	l	B	B	...



$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$
 $\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$
 $\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$
 $\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$
 $\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$

$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$
 $\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$
 $\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$
 $\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$
 $\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$

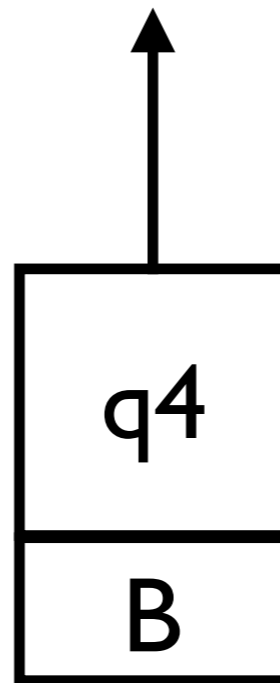
...	B	*	*	B	*	B	B	B	...
...	B	0	l	c	0	l	B	B	...



$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$
 $\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$
 $\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$
 $\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$
 $\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$

$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$
 $\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$
 $\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$
 $\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$
 $\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$

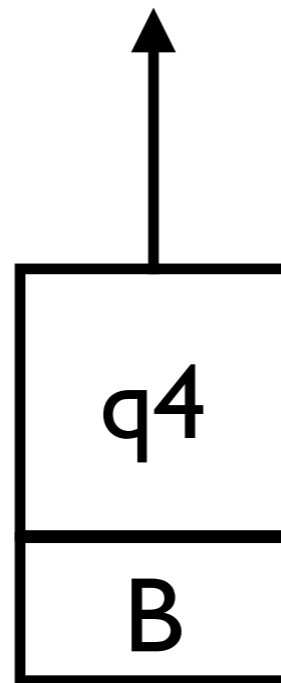
...	B	*	*	B	*	*	B	B	...
...	B	0	1	c	0	1	B	B	...



$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$
 $\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$
 $\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$
 $\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$
 $\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$

$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$
 $\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$
 $\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$
 $\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$
 $\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$

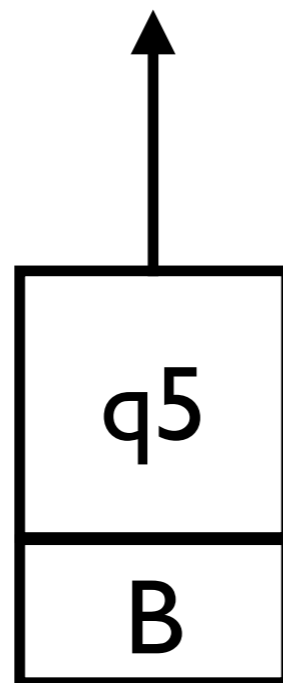
...	B	*	*	B	*	*	B	B	...
...	B	0	1	c	0	1	B	B	...



$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$
 $\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$
 $\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$
 $\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$
 $\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$

$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$
 $\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$
 $\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$
 $\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$
 $\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$

...	B	*	*	B	*	*	B	B	...
...	B	0	1	c	0	1	B	B	...

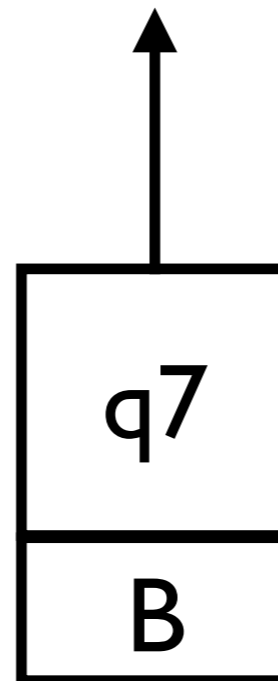


- If every symbols are checked, move right and enter q7

$$\begin{aligned}
\delta((q_1, B), (B, a)) &= ((q_2, a), (*, a), R) \\
\delta((q_2, a), (B, b)) &= ((q_2, a), (B, b), R) \\
\delta((q_2, a), (B, c)) &= ((q_3, a), (B, c), R) \\
\delta((q_3, a), (*, b)) &= ((q_3, a), (*, b), R) \\
\delta((q_3, a), (B, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (*, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (B, c)) &= ((q_5, B), (B, c), L)
\end{aligned}$$

$$\begin{aligned}
\delta((q_5, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (*, a)) &= ((q_1, B), (*, a), R) \\
\delta((q_5, B), (*, a)) &= ((q_7, B), (*, a), R) \\
\delta((q_7, B), (B, c)) &= ((q_8, B), (B, c), R) \\
\delta((q_8, B), (*, a)) &= ((q_8, B), (*, a), R) \\
\delta((q_8, B), (B, B)) &= ((q_9, B), (B, B), R)
\end{aligned}$$

...	B	*	*	B	*	*	B	B	...
...	B	0	1	c	0	1	B	B	...

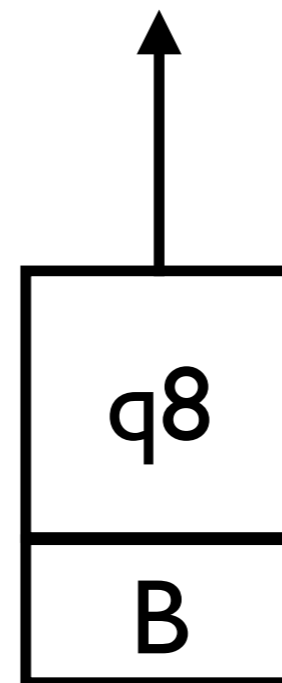


- If c is found, enter q8

$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$
 $\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$
 $\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$
 $\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$
 $\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$

$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$
 $\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$
 $\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$
 $\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$
 $\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$

...	B	*	*	B	*	*	B	B	...
...	B	0	1	c	0	1	B	B	...

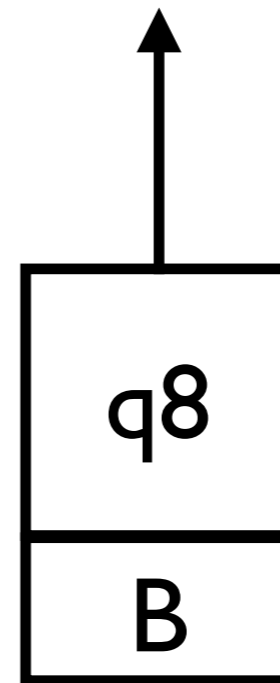


- move right until it finds B

$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$
 $\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$
 $\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$
 $\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$
 $\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$

$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$
 $\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$
 $\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$
 $\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$
 $\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$

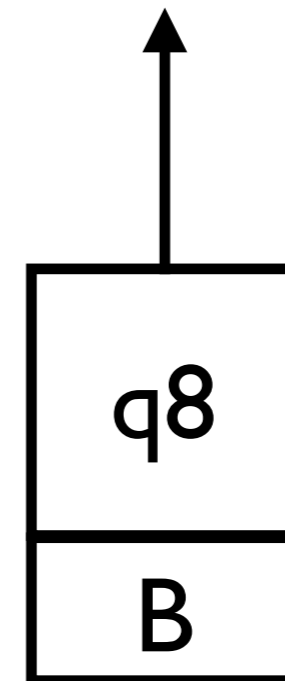
...	B	*	*	B	*	*	B	B	...
...	B	0	1	c	0	1	B	B	...



$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$
 $\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$
 $\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$
 $\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$
 $\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$

$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$
 $\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$
 $\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$
 $\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$
 $\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$

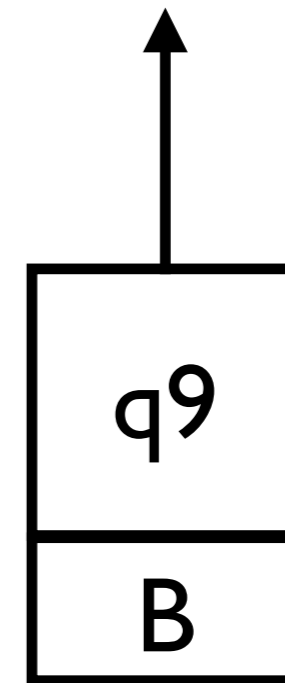
...	B	*	*	B	*	*	B	B	...
...	B	0	1	c	0	1	B	B	...



$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)$
 $\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)$
 $\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)$
 $\delta((q_3, a), (*, b)) = ((q_3, a), (*, b), R)$
 $\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)$
 $\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), L)$

$\delta((q_5, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (B, a)) = ((q_6, B), (B, a), L)$
 $\delta((q_6, B), (*, a)) = ((q_1, B), (*, a), R)$
 $\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$
 $\delta((q_7, B), (B, c)) = ((q_8, B), (B, c), R)$
 $\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)$
 $\delta((q_8, B), (B, B)) = ((q_9, B), (B, B), R)$

...	B	*	*	B	*	*	B	B	...
...	B	0	1	c	0	1	B	B	...



$$\begin{aligned}
\delta((q_1, B), (B, a)) &= ((q_2, a), (*, a), R) \\
\delta((q_2, a), (B, b)) &= ((q_2, a), (B, b), R) \\
\delta((q_2, a), (B, c)) &= ((q_3, a), (B, c), R) \\
\delta((q_3, a), (*, b)) &= ((q_3, a), (*, b), R) \\
\delta((q_3, a), (B, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (*, a)) &= ((q_4, B), (*, a), L) \\
\delta((q_4, B), (B, c)) &= ((q_5, B), (B, c), L)
\end{aligned}$$

$$\begin{aligned}
\delta((q_5, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (B, a)) &= ((q_6, B), (B, a), L) \\
\delta((q_6, B), (*, a)) &= ((q_1, B), (*, a), R) \\
\delta((q_5, B), (*, a)) &= ((q_7, B), (*, a), R) \\
\delta((q_7, B), (B, c)) &= ((q_8, B), (B, c), R) \\
\delta((q_8, B), (*, a)) &= ((q_8, B), (*, a), R) \\
\delta((q_8, B), (B, B)) &= ((q_9, B), (B, B), R)
\end{aligned}$$