COSE 215: Theory of Computation

Examples of Turing Machines (2)

Hakjoo Oh 2018 Spring

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

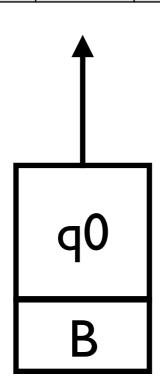
$$M = (\{q_0, q_1\} \times \{0, 1, B\}, \{0, 1\}, \{0, 1, B\}, \delta, (q_0, B), B, \{(q_1, B)\})$$

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. $\delta((q_1, a), B) = ((q_1, B), B, R)$

• • •	В	0	I	I	ı	В	В	В	• • •
-------	---	---	---	---	---	---	---	---	-------

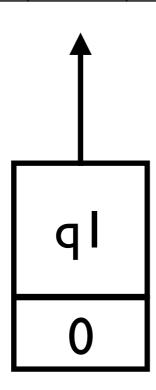


1.
$$\delta((q_0, B), a) = ((q_1, a), a, R)$$
 for $a = 0$ or $a = 1$

2.
$$\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$$

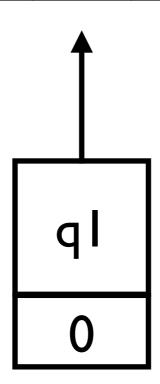
3.
$$\delta((q_1, a), B) = ((q_1, B), B, R)$$





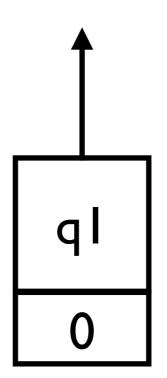
- 1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for a = 0 or a = 1
- 2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
- 3. $\delta((q_1, a), B) = ((q_1, B), B, R)$





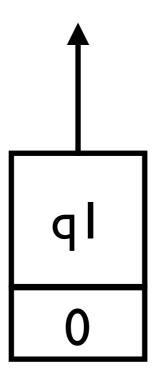
- 1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for a = 0 or a = 1
- 2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
- 3. $\delta((q_1, a), B) = ((q_1, B), B, R)$





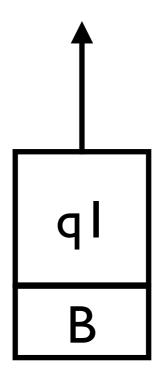
- 1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for a = 0 or a = 1
- 2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
- 3. $\delta((q_1, a), B) = ((q_1, B), B, R)$





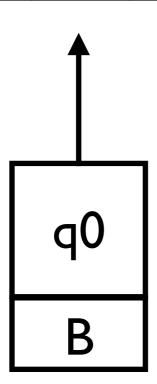
- 1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for a = 0 or a = 1
- 2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
- 3. $\delta((q_1, a), B) = ((q_1, B), B, R)$





- 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. $\delta((q_1, a), B) = ((q_1, B), B, R)$

• • •	В	I	0	0	0	В	В	В	• • •
-------	---	---	---	---	---	---	---	---	-------

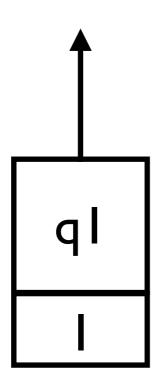


1.
$$\delta((q_0, B), a) = ((q_1, a), a, R)$$
 for $a = 0$ or $a = 1$

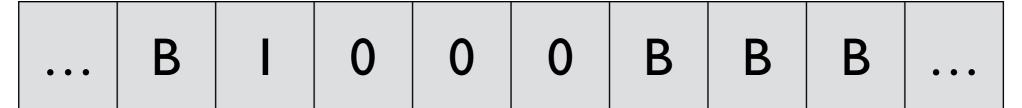
2.
$$\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$$

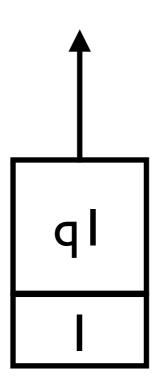
3.
$$\delta((q_1, a), B) = ((q_1, B), B, R)$$





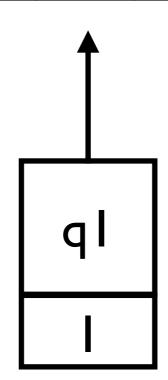
- 1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for a = 0 or a = 1
- 2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
- 3. $\delta((q_1, a), B) = ((q_1, B), B, R)$





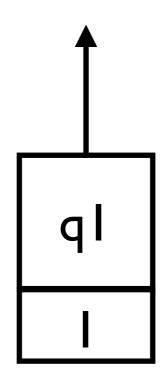
- 1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for a = 0 or a = 1
- 2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
- 3. $\delta((q_1, a), B) = ((q_1, B), B, R)$





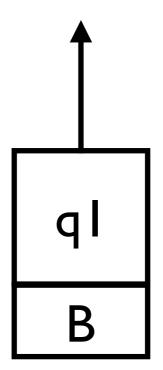
- 1. $\delta((q_0, B), a) = ((q_1, a), a, R)$ for a = 0 or a = 1
- 2. $\delta((q_1, a), \bar{a}) = ((q_1, a), \bar{a}, R)$
- 3. $\delta((q_1, a), B) = ((q_1, B), B, R)$





- 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. $\delta((q_1, a), B) = ((q_1, B), B, R)$

• • •	В	I	0	0	0	В	В	В	• • •



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 $L = \{wcw \mid w \in \{0, 1\}^+\}$.

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

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

$$- \{q_1, q_2, \dots, q_9\} \times \{0, 1, B\}$$

$$- \Gamma = \{B, *\} \times \{0, 1, c, B\}$$

$$- \Sigma = \{(B, 0), (B, 1), (B, c)\}$$

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

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

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

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

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

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

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

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

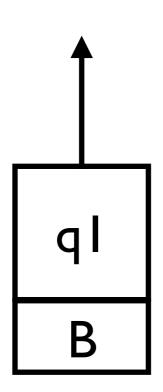
$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, c), R)$$

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

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

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a), ($$

• • •	В	В	В	В	В	В	В	В	• • •
• • •	В	0		С	0		В	В	• • •



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

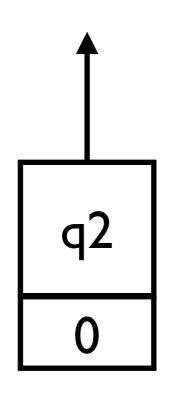
$$\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$$

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

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

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

• • •	В	*	В	В	В	В	В	В	• • •
• • •	В	0	I	С	0		В	В	• • •



In q2, moves right, looking for c

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

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

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

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

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

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

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

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

$$\delta((q_4, B), (B, a)) = ((q_4, B), (B, a), R)$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

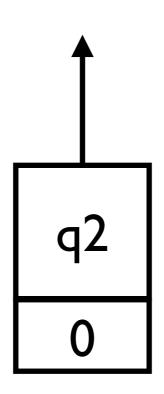
$$\delta((q_1, B), (B, a)) = ((q_1, B), (B, a), R)$$

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

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

$$\delta((q_1, B), (B, a)) = ($$

• • •	В	*	В	В	В	В	В	В	• • •
• • •	В	0	I	С	0	I	В	В	• • •



When found,

- enter q3
- continue right

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

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

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

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

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

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

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

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

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

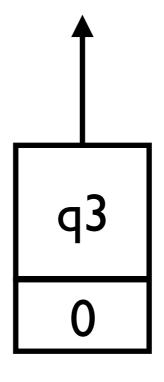
$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a), R)$$

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

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

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

• • •	В	*	В	В	В	В	В	В	• • •
• • •	В	0	I	С	0		В	В	• • •



In q3, look for the first unchecked symbol

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

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

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

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

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

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

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

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

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

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

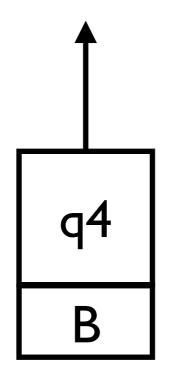
$$\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$$

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

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

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

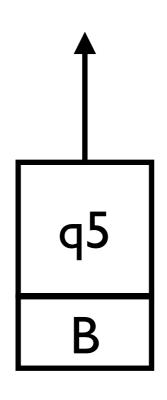
• • •	В	*	В	В	*	В	В	В	• • •
• • •	В	0	ı	С	0		В	В	• • •



- In q4, move left until it finds c
- When found, enter q5

$$\begin{array}{ll} \delta((q_1,B),(B,a)) = ((q_2,a),(*,a),R) & \delta((q_5,B),(B,a)) = ((q_6,B),(B,a),L) \\ \delta((q_2,a),(B,b)) = ((q_2,a),(B,b),R) & \delta((q_6,B),(B,a)) = ((q_6,B),(B,a),L) \\ \delta((q_2,a),(B,c)) = ((q_3,a),(B,c),R) & \delta((q_6,B),(*,a)) = ((q_6,B),(B,a),L) \\ \delta((q_3,a),(*,b)) = ((q_3,a),(*,b),R) & \delta((q_6,B),(*,a)) = ((q_1,B),(*,a),R) \\ \delta((q_3,a),(B,a)) = ((q_4,B),(*,a),L) & \delta((q_5,B),(*,a)) = ((q_7,B),(*,a),R) \\ \delta((q_7,B),(B,c)) = ((q_8,B),(*,a),R) \\ \delta((q_4,B),(*,a)) = ((q_4,B),(*,a),L) & \delta((q_8,B),(*,a)) = ((q_8,B),(*,a),R) \\ \delta((q_8,B),(*,a)) = ((q_9,B),(B,B),R) \end{array}$$

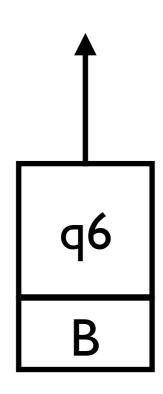
• • •	В	*	В	В	*	В	В	В	• • •
• • •	В	0		С	0		В	В	• • •



- If there is some unchecked symbol, enter q6

$$\begin{split} \delta((q_1,B),(B,a)) &= ((q_2,a),(*,a),R) \\ \delta((q_2,a),(B,b)) &= ((q_2,a),(B,b),R) \\ \delta((q_2,a),(B,c)) &= ((q_3,a),(B,c),R) \\ \delta((q_3,a),(*,b)) &= ((q_3,a),(*,b),R) \\ \delta((q_3,a),(B,a)) &= ((q_4,B),(*,a),L) \\ \delta((q_4,B),(*,a)) &= ((q_4,B),(*,a),L) \\ \delta((q_4,B),(B,c)) &= ((q_5,B),(B,c),L) \\ \end{split} \qquad \begin{array}{l} \delta((q_5,B),(B,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(B,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_1,B),(*,a)) &= ((q_1,B),(*,a$$

• • •	В	*	В	В	*	В	В	В	• • •
• • •	В	0	ı	С	0		В	В	• • •



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

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

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

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

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

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

$$\delta((q_4, B), (B, a)) = ((q_4, B), (B, a), R)$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

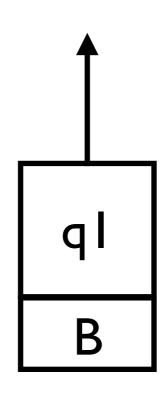
$$\delta((q_6, B), (B, a)) = ((q_1, B), (*, a), R)$$

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

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

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

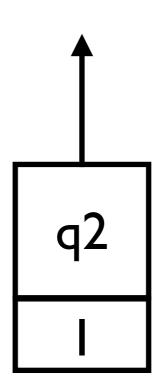
• • •	В	*	В	В	*	В	В	В	• • •
• • •	В	0		С	0		В	В	• • •



- Repeat the cycle

$$\begin{split} \delta((q_1,B),(B,a)) &= ((q_2,a),(*,a),R) \\ \delta((q_2,a),(B,b)) &= ((q_2,a),(B,b),R) \\ \delta((q_2,a),(B,c)) &= ((q_3,a),(B,c),R) \\ \delta((q_3,a),(*,b)) &= ((q_3,a),(*,b),R) \\ \delta((q_3,a),(B,a)) &= ((q_4,B),(*,a),L) \\ \delta((q_4,B),(*,a)) &= ((q_4,B),(*,a),L) \\ \delta((q_4,B),(B,c)) &= ((q_5,B),(B,c),L) \\ \end{split} \qquad \begin{array}{l} \delta((q_5,B),(B,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(B,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_6,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_6,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_1,B),(*,a)) &= ((q_1,B),(*,a$$

• • •	В	*	*	В	*	В	В	В	• • •
• • •	В	0		С	0		В	В	• • •



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

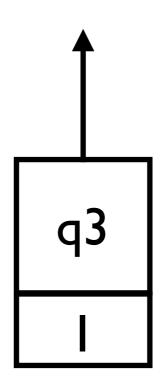
$$\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), R)$$

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

$$\delta((q_4, B), (*, a), R)$$

$$\begin{array}{ll} \delta((q_1,B),(B,a)) = ((q_2,a),(*,a),R) & \delta((q_5,B),(B,a)) = ((q_6,B),(B,a),L) \\ \delta((q_2,a),(B,b)) = ((q_2,a),(B,b),R) & \delta((q_6,B),(B,a)) = ((q_6,B),(B,a),L) \\ \delta((q_2,a),(B,c)) = ((q_3,a),(B,c),R) & \delta((q_6,B),(*,a)) = ((q_6,B),(B,a),L) \\ \delta((q_3,a),(*,b)) = ((q_3,a),(*,b),R) & \delta((q_6,B),(*,a)) = ((q_1,B),(*,a),R) \\ \delta((q_3,a),(B,a)) = ((q_4,B),(*,a),L) & \delta((q_5,B),(*,a)) = ((q_7,B),(*,a),R) \\ \delta((q_4,B),(*,a)) = ((q_4,B),(*,a),L) & \delta((q_6,B),(*,a)) = ((q_8,B),(*,a),R) \\ \delta((q_4,B),(*,a)) = ((q_4,B),(*,a),L) & \delta((q_8,B),(*,a)) = ((q_8,B),(*,a),R) \\ \delta((q_8,B),(*,a)) = ((q_9,B),(*,a),R) \\ \delta((q_8,B),(*,a)) = ((q_8,B),(*,a),R) \\ \delta((q_8,B),(*,a)) = ((q_8,B),(*,a),R) \\ \delta((q_8,B),(*,a)) = ((q_8,B),(*,a),R) \\ \delta((q_8,B),(*,a)) = ((q_8,B),(*,a),R) \\ \delta((q_8,B),$$

• • •	В	*	*	В	*	В	В	В	• • •
• • •	В	0	1	С	0		В	В	• • •



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

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

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

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

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

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

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

$$\delta((q_1,B),(B,a)) = ((q_2,a),(*,a),R) \qquad \delta((q_5,B),(B,a)) = ((q_6,B),(B,a),L)$$

$$\delta((q_2,a),(B,b)) = ((q_3,a),(B,c),R) \qquad \delta((q_6,B),(B,a)) = ((q_6,B),(B,a),L)$$

$$\delta((q_2,a),(B,c)) = ((q_3,a),(B,c),R) \qquad \delta((q_6,B),(*,a)) = ((q_6,B),(B,a),L)$$

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

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

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

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

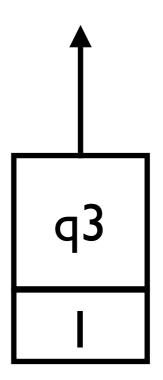
$$\delta((q_7,B),(B,c)) = ((q_8,B),(B,c),R)$$

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

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

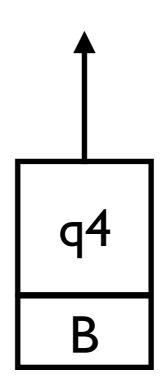
$$\delta((q_8,B),(*,a)) = ((q_8,B),(*,a),R)$$

• • •	В	*	*	В	*	В	В	В	• • •
• • •	В	0	1	С	0		В	В	• • •



$$\begin{array}{ll} \delta((q_1,B),(B,a)) = ((q_2,a),(*,a),R) & \delta((q_5,B),(B,a)) = ((q_6,B),(B,a),L) \\ \delta((q_2,a),(B,b)) = ((q_2,a),(B,b),R) & \delta((q_6,B),(B,a)) = ((q_6,B),(B,a),L) \\ \delta((q_2,a),(B,c)) = ((q_3,a),(B,c),R) & \delta((q_6,B),(*,a)) = ((q_6,B),(B,a),L) \\ \delta((q_3,a),(*,b)) = ((q_3,a),(*,b),R) & \delta((q_6,B),(*,a)) = ((q_1,B),(*,a),R) \\ \delta((q_3,a),(B,a)) = ((q_4,B),(*,a),L) & \delta((q_5,B),(*,a)) = ((q_7,B),(*,a),R) \\ \delta((q_4,B),(*,a)) = ((q_4,B),(*,a),L) & \delta((q_6,B),(*,a)) = ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) = ((q_1,B),(*,a),R) \\ \delta((q_6,B),(*,a)) = ((q_1,B),(*,a),R) \\ \delta((q_6,B),(*,a)) = ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) = ((q_6,B),(*,a),R) \\ \delta((q_6,B),$$

• • •	В	*	*	В	*	*	В	В	• • •
• • •	В	0	I	С	0	I	В	В	• • •



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

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

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

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

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

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

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

$$\delta((q_1,B),(B,a)) = ((q_2,a),(*,a),R) \qquad \delta((q_5,B),(B,a)) = ((q_6,B),(B,a),L)$$

$$\delta((q_2,a),(B,b)) = ((q_3,a),(B,c),R) \qquad \delta((q_6,B),(B,a)) = ((q_6,B),(B,a),L)$$

$$\delta((q_2,a),(B,c)) = ((q_3,a),(B,c),R) \qquad \delta((q_6,B),(*,a)) = ((q_6,B),(B,a),L)$$

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

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

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

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

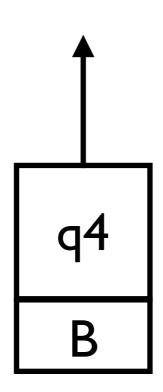
$$\delta((q_7,B),(B,c)) = ((q_8,B),(B,c),R)$$

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

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

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

• • •	В	*	*	В	*	*	В	В	• • •
• • •	В	0		C	0		В	В	• • •



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

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

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

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

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

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

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

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

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

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

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

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

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

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a)$$

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a)$$

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a)$$

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a)$$

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a)$$

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a)$$

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a)$$

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a)$$

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a)$$

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a)$$

$$\delta((q_3, a), (B, a)) = ((q_3, a), (B, a$$

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

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

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

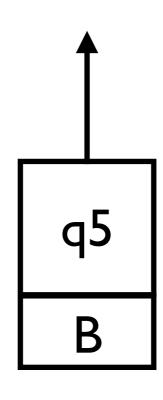
$$\delta((q_5, B), (*, a)) = ((q_7, B), (*, a), R)$$

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

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

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

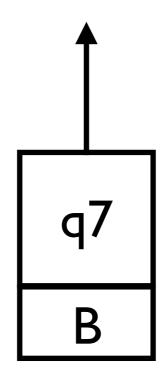
• • •	В	*	*	В	*	*	В	В	• • •
• • •	В	0		С	0	I	В	В	• • •



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

$$\begin{split} \delta((q_1,B),(B,a)) &= ((q_2,a),(*,a),R) \\ \delta((q_2,a),(B,b)) &= ((q_2,a),(B,b),R) \\ \delta((q_2,a),(B,c)) &= ((q_3,a),(B,c),R) \\ \delta((q_3,a),(*,b)) &= ((q_3,a),(*,b),R) \\ \delta((q_3,a),(B,a)) &= ((q_4,B),(*,a),L) \\ \delta((q_4,B),(*,a)) &= ((q_4,B),(*,a),L) \\ \delta((q_4,B),(B,c)) &= ((q_5,B),(B,c),L) \end{split} \qquad \begin{array}{l} \delta((q_5,B),(B,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(B,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) &= ((q_6,B),(*,a),R) \\ \delta((q_6,B),(*,a)) &= ((q_6,B),(*,a),$$

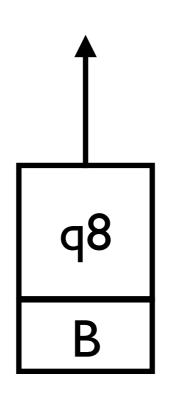
• • •	В	*	*	В	*	*	В	В	• • •
• • •	В	0	I	С	0		В	В	• • •



- If c is found, enter q8

$$\begin{split} \delta((q_1,B),(B,a)) &= ((q_2,a),(*,a),R) \\ \delta((q_2,a),(B,b)) &= ((q_2,a),(B,b),R) \\ \delta((q_2,a),(B,c)) &= ((q_3,a),(B,c),R) \\ \delta((q_3,a),(*,b)) &= ((q_3,a),(*,b),R) \\ \delta((q_3,a),(B,a)) &= ((q_4,B),(*,a),L) \\ \delta((q_4,B),(*,a)) &= ((q_4,B),(*,a),L) \\ \delta((q_4,B),(B,c)) &= ((q_5,B),(B,c),L) \end{split} \qquad \begin{array}{l} \delta((q_5,B),(B,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(B,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_6,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_7,B),(*,a),R) \\ \delta((q_7,B),(B,c)) &= ((q_8,B),(*,a),R) \\ \delta((q_8,B),(*,a)) &= ((q_8,B),(*,a),R) \\ \delta((q_8,B),(*,a)) &= ((q_9,B),(B,B),R) \end{split}$$

• • •	В	*	*	В	*	*	В	В	• • •
• • •	В	0		С	0		В	В	• • •



move right until it finds B

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

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

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

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

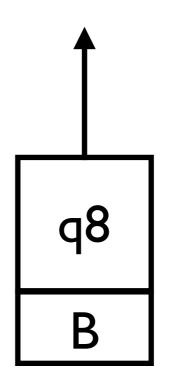
$$\delta((q_3, a), (B, a)) = ((q_4, B), (*, a), L)$$

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

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

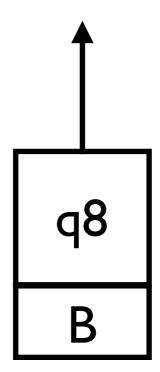
$$\begin{split} \delta((q_1,B),(B,a)) &= ((q_2,a),(*,a),R) \\ \delta((q_2,a),(B,b)) &= ((q_2,a),(B,b),R) \\ \delta((q_2,a),(B,c)) &= ((q_3,a),(B,c),R) \\ \delta((q_3,a),(*,b)) &= ((q_3,a),(*,b),R) \\ \delta((q_3,a),(B,a)) &= ((q_4,B),(*,a),L) \\ \delta((q_4,B),(*,a)) &= ((q_4,B),(*,a),L) \\ \delta((q_4,B),(B,c)) &= ((q_5,B),(B,c),L) \end{split} \qquad \begin{array}{l} \delta((q_5,B),(B,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(B,a)) &= ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) &= ((q_5,B),(*,a),R) \\ \delta((q_6,B),(*,a)) &= ((q_6,B),(*,a),R) \\ \delta((q_6,B),(*,a)) &= ((q_6,B),(*,a),$$

• • •	В	*	*	В	*	*	В	В	• • •
• • •	В	0	I	С	0	I	В	В	• • •



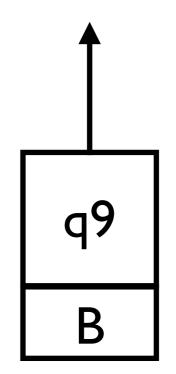
$$\begin{array}{ll} \delta((q_1,B),(B,a)) = ((q_2,a),(*,a),R) \\ \delta((q_2,a),(B,b)) = ((q_2,a),(B,b),R) \\ \delta((q_2,a),(B,c)) = ((q_3,a),(B,c),R) \\ \delta((q_3,a),(*,b)) = ((q_3,a),(*,b),R) \\ \delta((q_3,a),(B,a)) = ((q_4,B),(*,a),L) \\ \delta((q_4,B),(*,a)) = ((q_4,B),(*,a),L) \\ \delta((q_4,B),(B,c)) = ((q_5,B),(B,c),L) \\ \end{array} \begin{array}{ll} \delta((q_5,B),(B,a)) = ((q_6,B),(B,a),L) \\ \delta((q_6,B),(B,a)) = ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) = ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) = ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) = ((q_1,B),(*,a),R) \\ \delta((q_5,B),(*,a)) = ((q_5,B),(*,a),R) \\ \delta((q_6,B),(*,a)) = ((q_6,B),(B,a),L) \\ \delta((q_6,B),(*,a)) = ((q_6,B),(*,a),R) \\ \delta($$

• • •	В	*	*	В	*	*	В	В	• • •
• • •	В	0	I	С	0	I	В	В	• • •



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

• • •	В	*	*	В	*	*	В	В	• • •
• • •	В	0	I	С	0	I	В	В	• • •



$$\delta((q_1, B), (B, a)) = ((q_2, a), (*, a), R)
\delta((q_2, a), (B, b)) = ((q_2, a), (B, b), R)
\delta((q_2, a), (B, c)) = ((q_3, a), (B, c), R)
\delta((q_3, a), (*, b)) = ((q_4, B), (*, a), L)
\delta((q_4, B), (*, a)) = ((q_4, B), (*, a), L)
\delta((q_4, B), (B, c)) = ((q_4, B), (*, a), L)
\delta((q_4, B), (B, c)) = ((q_4, B), (*, a), L)
\delta((q_4, B), (B, c)) = ((q_4, B), (*, a), L)
\delta((q_4, B), (B, c)) = ((q_4, B), (*, a), L)
\delta((q_4, B), (B, c)) = ((q_5, B), (B, c), R)
\delta((q_8, B), (*, a)) = ((q_8, B), (*, a), R)
\delta((q_8, B), (*, a)) = ((q_9, B), (B, C), R)
\delta((q_8, B), (*, a)) = ((q_9, B), (B, B), R)$$