

Recall the evaluation rules for state:

$$\begin{array}{c}
 \frac{}{z \mid s \Downarrow z \mid s} \quad \frac{t_1 \mid s_1 \Downarrow z_1 \mid s_2 \quad t_2 \mid s_2 \Downarrow z_2 \mid s_3}{t_1 + t_2 \mid s_1 \Downarrow z_1 + z_2 \mid s_3} \quad \frac{}{\lambda x.t \mid s \Downarrow \lambda x.t \mid s} \\
 \frac{t_1 \mid s_1 \Downarrow \lambda x.t \mid t_2 \quad t_2 \mid s_2 \Downarrow w \mid s_3 \quad t[w/x] \mid s_3 \Downarrow v \mid s_4}{t_1 t_2 \mid s_1 \Downarrow v \mid s_4} \quad \frac{}{\text{get} \mid s \Downarrow s \mid s} \quad \frac{t \mid s_1 \Downarrow v \mid s_2}{\text{put } t \mid s_1 \Downarrow v \mid v}
 \end{array}$$

Note that `put t` evaluates to the value of t .

1. The above rules use *left-to-right* evaluation. Give the result of evaluating each of the following terms (just the value, not the state) using both left-to-right and *right-to-left* evaluation orders.

Expression	Initial state	Result in ltr	Result in rtl
<code>put 3 + get</code>	1	6	4
<code>($\lambda a.$put (get + a)) get</code>	1	2	2
<code>($\lambda a.$$\lambda b.$$a + b$) get (put 3)</code>	1	4	6

2. Give the derivation tree for `($\lambda a.$ put a) get | 3 \Downarrow 3 | 3`.

$$\frac{\frac{\lambda a.\text{put } a \mid 3 \Downarrow \lambda a.\text{put } a \mid 3 \quad \text{get} \mid 3 \Downarrow 3 \mid 3}{(\lambda a.\text{put } a) \text{ get} \mid 3 \Downarrow 3 \mid 3} \quad \frac{3 \mid 3 \Downarrow 3 \mid 3}{(\text{put } a)[3/a] \mid 3 \Downarrow 3 \mid 3}}{(\lambda a.\text{put } a) \text{ get} \mid 3 \Downarrow 3 \mid 3}$$