

$\boxed{\Psi \vdash e : \sigma}$	$\Psi ::= \emptyset \mid \Psi, x : \sigma$
$\frac{\text{S-T-VAR} \quad x : \sigma \in \Psi}{\Psi \vdash x : \sigma}$	$\frac{\text{S-T-ABS} \quad \Psi, x : \sigma_1 \vdash e : \sigma_2}{\Psi \vdash \lambda x. e : \sigma_1 \rightarrow \sigma_2}$
$\frac{\text{S-T-APP} \quad \Psi \vdash e_1 : \sigma_2 \rightarrow \sigma \quad \Psi \vdash e_2 : \sigma_2}{\Psi \vdash e_1(e_2) : \sigma}$	$\frac{\text{S-T-STRINGIN-I} \quad s \in \mathcal{L}\{r\}}{\Psi \vdash \text{rstr}[s] : \text{stringin}[r]}$
$\frac{\text{S-T-CONCAT} \quad \Psi \vdash e_1 : \text{stringin}[r_1] \quad \Psi \vdash e_2 : \text{stringin}[r_2]}{\Psi \vdash \text{rconcat}(e_1; e_2) : \text{stringin}[r_1 \cdot r_2]}$	
$\frac{\text{S-T-CASE} \quad \Psi \vdash e_1 : \text{stringin}[r] \quad \Psi \vdash e_2 : \sigma \quad \Psi, x : \text{stringin}[\text{lhead}(r)], y : \text{stringin}[\text{ltail}(r)] \vdash e_3 : \sigma}{\Psi \vdash \text{strcase}(e_1; e_2; x.y.e_3) : \sigma}$	
$\frac{\text{S-T-REPLACE} \quad \Psi \vdash e_1 : \text{stringin}[r_1] \quad \Psi \vdash e_2 : \text{stringin}[r_2] \quad \text{lreplace}(r; r_1; r_2) = r'}{\Psi \vdash \text{rreplace}[r](e_1; e_2) : \text{stringin}[r']}$	
$\frac{\text{S-T-SAFE} \text{COERCE} \quad \Psi \vdash e : \text{stringin}[r'] \quad \mathcal{L}\{r'\} \subseteq \mathcal{L}\{r\}}{\Psi \vdash \text{rcoerce}[r](e) : \text{stringin}[r]}$	
$\frac{\text{S-T-CHECK} \quad \Psi \vdash e_0 : \text{stringin}[r_0] \quad \Psi, x : \text{stringin}[r] \vdash e_1 : \sigma \quad \Psi \vdash e_2 : \sigma}{\Psi \vdash \text{rcheck}[r](e_0; x.e_1; e_2) : \sigma}$	

**Figure 1: Typing rules for  $\lambda_{RS}$ . The typing context  $\Psi$  is standard.**

$e \Downarrow e$

$\frac{\text{S-E-RSTR}}{\text{rstr}[s] \Downarrow \text{rstr}[s]}$	$\frac{\text{S-E-CONCAT}}{e_1 \Downarrow \text{rstr}[s_1] \quad e_2 \Downarrow \text{rstr}[s_2] \quad \text{rconcat}(e_1; e_2) \Downarrow \text{rstr}[s_1 s_2]}$
$\frac{\text{S-E-CASE-}\epsilon}{e_1 \Downarrow \text{rstr}[\epsilon] \quad e_2 \Downarrow v_2 \quad \text{strcase}(e_1; e_2; e_3) \Downarrow v_2}$	
$\frac{\text{S-E-CASE-CONCAT}}{e_1 \Downarrow \text{rstr}[ps] \quad e_3 \Downarrow x.y.e_4 \quad [p/x][s/y]e_4 \Downarrow v \quad \text{strcase}(e_1; e_2; e_3) \Downarrow v}$	
$\frac{\text{S-E-REPLACE}}{e_1 \Downarrow \text{rstr}[e_1] \quad e_2 \Downarrow \text{rstr}[s_2] \quad \text{subst}(r; s_1; s_2) = s \quad \text{rreplace}[r](e_1; e_2) \Downarrow \text{rstr}[s]}$	
$\frac{\text{S-E-SAFE} \text{COERCE}}{e \Downarrow \text{rstr}[s] \quad \text{rcoerce}[r](e) \Downarrow \text{rstr}[s]}$	
$\frac{\text{S-E-CHECK-OK}}{e \Downarrow \text{rstr}[s] \quad s \in \mathcal{L}\{r\} \quad [\text{rstr}[s]/x]e_1 \Downarrow v \quad \text{rcheck}[r](e; x.e_1; e_2) \Downarrow v}$	
$\frac{\text{S-E-CHECK-NOTOK}}{e \Downarrow \text{rstr}[s] \quad s \notin \mathcal{L}\{r\} \quad \text{rcheck}[r](e; x.e_1; e_2) \Downarrow e_2}$	

**Figure 2: Big step semantics for  $\lambda_{RS}$ .**

$\boxed{\Theta \vdash \iota : \tau}$	$\Theta ::= \emptyset \mid \Theta, x : \tau$
$\frac{\text{P-T-VAR} \quad x : \tau \in \Theta}{\Theta \vdash x : \tau}$	$\frac{\text{P-T-ABS} \quad \Theta, x : \tau_1 \vdash \iota_2 : \tau_2}{\Theta \vdash \lambda x. \iota_2 : \tau_1 \rightarrow \tau_2}$
$\frac{\text{P-T-APP} \quad \Theta \vdash \iota_1 : \tau_2 \rightarrow \tau \quad \Theta \vdash \iota_2 : \tau_2}{\Theta \vdash \iota_1(\iota_2) : \tau}$	$\frac{\text{P-T-STRING}}{\Theta \vdash \text{str}[s] : \text{string}}$
$\frac{\text{P-T-REGEX}}{\Theta \vdash \text{rx}[r] : \text{regex}}$	$\frac{\text{P-T-CONCAT} \quad \Theta \vdash \iota_1 : \text{string} \quad \Theta \vdash \iota_2 : \text{string}}{\Theta \vdash \text{concat}(\iota_1; \iota_2) : \text{string}}$
$\frac{\text{P-T-CASE} \quad \Theta \vdash \iota_1 : \text{string} \quad \Theta \vdash \iota_2 : \tau \quad \Theta, x : \text{string}, y : \text{string} \vdash \iota_3 : \tau}{\Theta \vdash \text{pstrcase}(\iota_1; \iota_2; \iota_3) : \tau}$	
$\frac{\text{P-T-REPLACE} \quad \Theta \vdash \iota_1 : \text{regex} \quad \Theta \vdash \iota_2 : \text{string} \quad \Theta \vdash \iota_3 : \text{string}}{\Theta \vdash \text{preplace}(\iota_1; \iota_2; \iota_3) : \text{string}}$	
$\frac{\text{P-T-CHECK} \quad \Theta \vdash \iota_r : \text{regex} \quad \Theta \vdash \iota_1 : \text{string} \quad \Theta, x : \text{string} \vdash \iota_2 : \sigma \quad \Theta \vdash \iota_3 : \sigma}{\Theta \vdash \text{check}(\iota_r; \iota_1; x.\iota_2; \iota_3) : \sigma}$	

**Figure 3: Typing rules for  $\lambda_P$ . The typing context  $\Theta$  is standard.**

$\iota \Downarrow \iota$

$\frac{\text{P-E-ABS}}{\lambda x. e \Downarrow \lambda x. e}$	$\frac{\text{P-E-APP} \quad \iota_1 \Downarrow \lambda x. \iota_3 \quad \iota_2 \Downarrow \iota'_2 \quad [\iota_3/x]\iota'_2 \Downarrow v}{\iota_1(\iota_2) \Downarrow v}$	
$\frac{\text{P-E-STR}}{\text{str}[s] \Downarrow \text{str}[s]}$	$\frac{\text{P-E-RX}}{\text{rx}[r] \Downarrow \text{rx}[r]}$	$\frac{\text{P-E-CONCAT} \quad \iota_1 \Downarrow \text{str}[s_1] \quad \iota_2 \Downarrow \text{str}[s_2]}{\text{concat}(\iota_1; \iota_2) \Downarrow \text{str}[s_1 s_2]}$
$\frac{\text{P-E-CASE-}\epsilon \quad \iota_1 \Downarrow \text{str}[\ ] \quad \iota_2 \Downarrow \iota_2}{\text{pstrcase}(\iota_1; \iota_2; \iota_3) \Downarrow v_2}$		
$\frac{\text{P-E-CASE-CONCAT} \quad \iota_1 \Downarrow \text{str}[ps] \quad x.y.\iota_3 \Downarrow \iota_4 \quad [p/x][s/y]\iota_4 \Downarrow v}{\text{pstrcase}(\iota_1; \iota_2; \iota_3) \Downarrow v}$		
$\frac{\text{P-E-REPLACE} \quad \iota_1 \Downarrow \text{rx}[r] \quad \iota_2 \Downarrow \text{str}[s_2] \quad \iota_3 \Downarrow \text{str}[s_3] \quad \text{subst}(r; s_2; s_3) = s}{\text{preplace}(\iota_1; \iota_2; \iota_3) \Downarrow \text{str}[s]}$		
$\frac{\text{P-E-CHECK-OK} \quad \iota \Downarrow \text{str}[s] \quad s \in \mathcal{L}\{r\}}{\text{check}(\text{rx}[r]; \iota; x.\iota_1; \iota_2) \Downarrow \iota_3}$		
$\frac{\text{P-E-CHECK-NOTOK} \quad \iota \Downarrow \text{str}[s] \quad s \notin \mathcal{L}\{r\}}{\text{check}(\text{rx}[r]; \iota; x.\iota_1; \iota_2) \Downarrow \iota_2}$		

**Figure 4: Big step semantics for  $\lambda_P$**

$$\boxed{\Psi \vdash \llbracket e \rrbracket = \iota}$$

$$\begin{array}{c}
\text{TR-VAR} \\
\hline
\Psi \vdash \llbracket x \rrbracket = x
\end{array}
\quad
\begin{array}{c}
\text{TR-ABS} \\
\Psi \vdash \llbracket e \rrbracket = \iota \\
\hline
\Psi \vdash \llbracket \lambda x. e \rrbracket = \lambda x. \iota
\end{array}
\quad
\begin{array}{c}
\text{TR-APP} \\
\Psi \vdash \llbracket e_1 \rrbracket = \iota_1 \quad \Psi \vdash \llbracket e_2 \rrbracket = \iota_2 \\
\hline
\Psi \vdash \llbracket e_1(e_2) \rrbracket = \iota_1(\iota_2)
\end{array}
\quad
\begin{array}{c}
\text{TR-CASE} \\
\Psi \vdash \llbracket e_1 \rrbracket = \iota_1 \quad \Psi \vdash \llbracket e_2 \rrbracket = \iota_2 \quad \Psi \vdash \llbracket e_3 \rrbracket = \iota_3 \\
\hline
\Psi \vdash \llbracket \text{strcase}(e_1; e_2; e_3) \rrbracket = \text{pstrcase}(\iota_1; \iota_2; \iota_3)
\end{array}$$
  

$$\begin{array}{c}
\text{TR-STRING} \\
\hline
\Psi \vdash \llbracket \text{rstr}[s] \rrbracket = \text{str}[s]
\end{array}
\quad
\begin{array}{c}
\text{TR-CONCAT} \\
\Psi \vdash \llbracket e_1 \rrbracket = \iota_1 \quad \Psi \vdash \llbracket e_2 \rrbracket = \iota_2 \\
\hline
\Psi \vdash \llbracket \text{rconcat}(e_1; e_2) \rrbracket = \text{concat}(\iota_1; \iota_2)
\end{array}
\quad
\begin{array}{c}
\text{TR-SUBST} \\
\Psi \vdash \llbracket e_1 \rrbracket = \iota_1 \quad \Psi \vdash \llbracket e_2 \rrbracket = \iota_2 \\
\hline
\Psi \vdash \llbracket \text{rreplace}[r](e_1; e_2) \rrbracket = \text{replace}(\text{rx}[r]; \iota_1; \iota_2)
\end{array}$$
  

$$\begin{array}{c}
\text{TR-SAFE COERCE} \\
\Psi \vdash \llbracket e \rrbracket = \iota \\
\hline
\Psi \vdash \llbracket \text{rcoerce}[r'](e) \rrbracket = \iota
\end{array}
\quad
\begin{array}{c}
\text{TR-CHECK} \\
\Psi \vdash \llbracket e \rrbracket = \iota_1 \quad \Psi \vdash \llbracket e_1 \rrbracket = \iota_1 \quad \Psi \vdash \llbracket e_2 \rrbracket = \iota_2 \\
\hline
\Psi \vdash \llbracket \text{rcheck}[r](e; x.e_1; e_2) \rrbracket = \text{check}(\text{rx}[r]; \iota; x.\iota_1; \iota_2)
\end{array}$$

**Figure 5: Translation from source terms ( $e$ ) to target terms ( $\iota$ ). The translation is type-directed.**

Note that S-E-ABS and S-E-APP are excluded from Figure 1 due to space constraints. However, they resemble the corresponding rules for  $\lambda_P$ ; see the paper for a full definition.