$termvar$, x term variable

$index$, i, j, k, n, m, p

$$
\begin{array}{lcl}
T & ::= & \\
 & | & \mathbf{bool} \\
 & | & \mathbf{int} \\
 & | & \langle T_1, \, .. \, , T_n \rangle \\
 & | & T@r \\
 & | & T@(r_1, \, .. \, , r_n) \\
 & | & T[r_1, \, .. \, , r_n] \\
 & | & T[r_1/r'_1, \, .. \, , r_n/r'_n] \\
 & | & \mathbf{coloring}\,(r) \\
 & | & \mathbf{exists}\, r_1, \, .. \, , r_n.(T_1, \, .. \, , T_m), \Phi, Q \rightarrow \mathbf{Tr} \\
 & & \\
fresh & ::= & \\
 & | & iv \\
 & & \\
fns & ::= & \\
 & | & \mathbf{apply}\,(S, E) \\
 & | & valid\_interleave(S, C, E_1, \, .. \, , E_n) \\
 & | & \mathbf{taskid}\, fresh \\
 & | & mark\_coherence(E, M, \mathbf{taskid}\,) \\
 & & \\
r & ::= & \\
 & | & \mathbf{nullr} \\
 & | & \mathbf{notnullr} \\
 & & \\
rr & ::= & \\
 & | & [r_1, \, .. \, , r_n] \\
 & & \\
l & ::= & \\
 & | & \mathbf{nil} \\
 & & \\
\Gamma & ::= & \\
 & | & \{(e_1 : T_1), \, .. \, , (e_n : T_n)\} \\
 & | & \varnothing \\
 & & \\
\Omega & ::= & \\
 & | & \{\omega_1, \, .. \, , \omega_n\} \\
 & | & \varnothing \\
 & & \\
\Omega^* & ::= & \\
 & | & \{\omega_1, \, .. \, , \omega_n\} \\
 & | & \mathbf{emptyOst} \\
 & & \\
rs & ::= & \\
 & | & \{r_1, \, .. \, , r_n\} \\
 & | & \varnothing \\
 & & \\
\omega & ::= &
\end{array}
$$

	$\vert$	$r_1 \leq r_2$
	$\vert$	$r_1 * r_2$
Φ	$::=$	
	$\vert$	$\{\phi_1, .., \phi_n\}$
	$\vert$	$\varnothing$
Φ^*	$::=$	
	$\vert$	$\{\phi_1, .., \phi_n\}$
	$\vert$	**emptyPst**
ϕ	$::=$	
	$\vert$	**reads** (r)
	$\vert$	**writes** (r)
	$\vert$	**reducesid** (r)
Q	$::=$	
	$\vert$	$\{q_1, .., q_n\}$
q	$::=$	
	$\vert$	**atomic** (r)
	$\vert$	**simult** (r)
M	$::=$	
	$\vert$	$M[[Q]]$
L	$::=$	
	$\vert$	**nil**
	$\vert$	$L[(e_1, v_1), .., (e_n, v_n)]$
	$\vert$	$L[v/id]$
K	$::=$	
H	$::=$	
	$\vert$	$H(l)$
S	$::=$	
C	$::=$	
E	$::=$	
	$\vert$	$[]$
	$\vert$	$[e]$
	$\vert$	$E + +[e]$
ρ	$::=$	

v	$::=$		
	$\mid$	bv	
	$\mid$	iv	
	$\mid$	$\langle v_1, v_2 \rangle$	
	$\mid$	**null**	
	$\mid$	l	
	$\mid$	$\langle\langle \rho_1, \,..\,, \rho_n, v \rangle\rangle$	
	$\mid$	H	
	$\mid$	K	
	$\mid$	**place**	
bv	$::=$		
	$\mid$	**true**	constant true
	$\mid$	**false**	constant false
iv	$::=$		
	$\mid$	0	
	$\mid$	$S\ iv$	
ee	$::=$		
	$\mid$	$(e_1, \,..\,, e_n)$	
id	$::=$		
e	$::=$		
	$\mid$	x	
	$\mid$	**new** $T@r$	
	$\mid$	**null** $T@r$	
	$\mid$	**isnull** (e)	
	$\mid$	**upregion** $(e, r_1, \,..\,, r_n)$	
	$\mid$	**downregion** $(e, r_1, \,..\,, r_n)$	
	$\mid$	**read** (e)	
	$\mid$	**excl**	
	$\mid$	**read** $(e_1,$ **excl** $, e_2, e_3)$	
	$\mid$	**write** (e_1, e_2)	
	$\mid$	**reduce** (id, e_1, e_2)	
	$\mid$	**reduceid** (l, e_1, e_2, e_3)	
	$\mid$	**newcolor** r	
	$\mid$	**color** (e_1, e_2, e_3)	
	$\mid$	$e_1 + e_2$	
	$\mid$	$e_1 < e_2$	
	$\mid$	**let** $id : T = e_1 \in e_2$	
	$\mid$	**if b then** $c0$ **else** $c1$	conditional
	$\mid$	$id[r_1, \,..\,, r_n](e_1, \,..\,, e_m)$	
	$\mid$	**partition** r_p **using** e_1 **as** $r_1, \,..\,, r_n \in e_2$	
	$\mid$	**pack** e_1 **as** T	
	$\mid$	**unpack** e_1 **as** $id : T \in e_2$	

	|	**function** $id[r_1, .., r_n](e_1, .., e_m)$		
	|	$\{$ **function** $id_1\, rr_1\, ee_1, .., $ **function** $id_n\, rr_n\, ee_n \}$		
	|	L		
	|	$e : T$		
	|	**place**		
	|	bv		
	|	iv		
	|	$\langle v_1, v_2 \rangle$		
	|	**null**		
	|	l		
	|	$\langle\langle \rho_1, .., \rho_n, v \rangle\rangle$		
	|	H		
	|	K		
	|	**true**		constant true
	|	**false**		constant false
	|	0		
	|	$S\ iv$		
formula	::=			
	|	*judgement*		judgement
	|	$\neg formula$	M	negated formula
	|	$(formula)$	M	bracketed
	|	$\forall_i.\phi \in \Phi$	M	for all variables in domain of Φ
	|	$\forall_i.\phi \in \Phi^*$	M	for all variables in domain of Φ^*
	|	$\exists_i.\phi \in \Phi$	M	for all variables in domain of Φ
	|	$\forall_i.\omega \in \Omega$	M	for all variables in domain of Ω
	|	$\forall_i.\omega \in \Omega^*$	M	for all variables in domain of Ω^*
	|	$\exists_i.\omega \in \Omega$	M	for all variables in domain of Ω
	|	$\exists_i.\omega \in \Omega^*$	M	for all variables in domain of Ω^*
	|	$\forall_i.formula$	M	for all variables in i and *formula*
	|	$\exists_{formula_1}.formula_2$	M	for all variables in $formula_1$ and *for*
	|	$\exists_{formula_1}.formula_2$ where $formula_3$	M	exists $formula_1$ and $formula_2$ where
	|	$\Gamma(id)$		lookup
	|	$formula_1 = formula_2$		equality
	|	$formula_1 \wedge formula_2$		equality
	|	$\bigwedge_i .formula$	M	and fold on i and *formula*
	|	$formula_1 \cap formula_2$	M	
	|	$formula_1 \cup formula_2$	M	
	|	$formula_1 \subseteq formula_2$	M	
	|	$formula_1 \in formula_2$	M	
	|	$\Gamma, \Phi, \Omega \rightarrow T$		impl
	|	$\Gamma, \Phi, Q \rightarrow T$		impl
	|	$r_1, .., r_n$		region list
	|	ϕ		phi
	|	ω		om
	|	Ω		

| | Φ
| | Φ^*
| | $\Phi[r_1/r'_1, .., r_n/r'_n]$
| | $T[r_1/r'_1, .., r_n/r'_n]$
| | $M[\rho_1/r'_1, .., \rho_n/r'_n]$
| | $M[[T]]$
| | $M[[Q]]$
| | $\mathbf{domain}\,(S)$
| | $M(r)$
| | $\Gamma[r_1/r'_1, .., r_n/r'_n]$
| | $\Gamma[e_1/T_1, .., e_n/T_n]$
| | Γ
| | $\Gamma[T[r_1/r'_1, .., r_n/r'_n]/id]$
| | $\Omega[r_1/r'_1, .., r_n/r'_n]$
| | $regions\_of(\Gamma, T)$
| | $regions\_of(\Gamma, T1, T_2)$
| | rs
| | T
| | fns
| | S
| | C
| | M
| | v
| | E
| | L
| | $\overline{e_i = l_i}^{\,i<n}$

$terminals$ ::=
| | $\exists$
| | $\forall$
| | $\in$
| | ω
| | ϕ
| | ρ
| | $\vee$
| | $\wedge$
| | $\neg$
| | $*$
| | $\leq$
| | $\longrightarrow$
| | $\rightarrow$
| | $\Rightarrow$
| | λ
| | $\mapsto$
| | $\vdash$
| | $\varnothing$

	$\vert$	$\varnothing$	
	$\vert$	$\varnothing$	
	$\vert$	$\varnothing$	
	$\vert$	$\times$	
	$\vert$	$<:$	
	$\vert$	$\langle$	
	$\vert$	$\rangle$	
	$\vert$	$<$	
	$\vert$	$\Downarrow$	
	$\vert$	σ	
	$\vert$	Γ	
	$\vert$	ε	
Jtype	$::=$		
	$\vert$	$\Gamma, \Phi, \Omega \vdash e : T$	Typing
Jop	$::=$		
	$\vert$	$M, L, H, S, C \vdash e \mapsto v, E$	Evaluation
judgement	$::=$		
	$\vert$	*Jtype*	
	$\vert$	*Jop*	
user_syntax	$::=$		
	$\vert$	*termvar*	
	$\vert$	*index*	
	$\vert$	T	
	$\vert$	*fresh*	
	$\vert$	*fns*	
	$\vert$	r	
	$\vert$	rr	
	$\vert$	l	
	$\vert$	Γ	
	$\vert$	Ω	
	$\vert$	Ω^*	
	$\vert$	rs	
	$\vert$	ω	
	$\vert$	Φ	
	$\vert$	Φ^*	
	$\vert$	ϕ	
	$\vert$	Q	
	$\vert$	q	
	$\vert$	M	
	$\vert$	L	
	$\vert$	K	
	$\vert$	H	
	$\vert$	S	

$|\quad C$
$|\quad E$
$|\quad \rho$
$|\quad v$
$|\quad bv$
$|\quad iv$
$|\quad ee$
$|\quad id$
$|\quad e$
$|\quad formula$
$|\quad terminals$

$\boxed{\Gamma, \Phi, \Omega \vdash e : T}$ Typing

$$\frac{\Gamma, \Phi, \Omega \vdash e_1 : T@(r_1, .., r_n)}{\Gamma, \Phi, \Omega \vdash \textbf{read}\,(e_1) : T} \quad \text{T\_READ}$$

$$\frac{\begin{array}{c}\Gamma, \Phi, \Omega \vdash e_1 : T@(r_1, .., r_n) \\ \Gamma, \Phi, \Omega \vdash e_2 : T\end{array}}{\Gamma, \Phi, \Omega \vdash \textbf{write}\,(e_1, e_2) : T@(r_1, .., r_n)} \quad \text{T\_WRITE}$$

$$\frac{\begin{array}{c}\Gamma, \Phi, \Omega \vdash e_1 : T_1@(r_1, .., r_n) \\ \Gamma, \Phi, \Omega \vdash e_2 : T_2\end{array}}{\Gamma, \Phi, \Omega \vdash \textbf{reduce}\,(id, e_1, e_2) : T_1@(r_1, .., r_n)} \quad \text{T\_REDUCE}$$

$$\frac{}{\Gamma, \Phi, \Omega \vdash \textbf{new}\; T@r : T@r} \quad \text{T\_NEW}$$

$$\frac{\Gamma, \Phi, \Omega \vdash e : T@(r'_1, .., r'_k)}{\Gamma, \Phi, \Omega \vdash \textbf{upregion}\,(e_1, r_1, .., r_n) : T@(r_1, .., r_n)} \quad \text{T\_UPRGN}$$

$$\frac{\Gamma, \Phi, \Omega \vdash e : T@(r'_1, .., r'_k)}{\Gamma, \Phi, \Omega \vdash \textbf{downregion}\,(e, r_1, .., r_n) : T@(r_1, .., r_n)} \quad \text{T\_DNRGN}$$

$$\frac{}{\Gamma, \Phi, \Omega \vdash \textbf{newcolor}\; r : \textbf{coloring}\,(r)} \quad \text{T\_NEWCOLOR}$$

$$\frac{\begin{array}{c}\Gamma, \Phi, \Omega \vdash e_1 : \textbf{coloring}\,(r) \\ \Gamma, \Phi, \Omega \vdash e_2 : T@r \\ \Gamma, \Phi, \Omega \vdash e_3 : \textbf{int}\end{array}}{\Gamma, \Phi, \Omega \vdash \textbf{color}\,(e_1, e_2, e_3) : \textbf{coloring}\,(r)} \quad \text{T\_COLOR}$$

$$\frac{\begin{array}{c}\Gamma, \Phi, \Omega \vdash e_1 : \textbf{coloring}\,(r_p) \\ \Gamma, \Phi, \Omega' \vdash e_2 : T\end{array}}{\Gamma, \Phi, \Omega \vdash \textbf{partition}\; r_p \;\textbf{using}\; e_1 \;\textbf{as}\; r_1, .., r_k \in e_2 : T} \quad \text{T\_PARTITION}$$

$$\frac{\Gamma, \Phi, \Omega \vdash e_1 : T_2[r_1/r'_1, .., r_k/r'_k]}{\Gamma, \Phi, \Omega \vdash \textbf{pack}\; e_1 \;\textbf{as}\; T_1[r_1, .., r_k] : T_1} \quad \text{T\_PACK}$$

$$\frac{\begin{array}{c}\Gamma, \Phi, \Omega \vdash e_1 : T_1 \\ \Gamma', \Phi, \Omega' \vdash e_2 : T_3\end{array}}{\Gamma, \Phi, \Omega \vdash \textbf{unpack}\; e_1 \;\textbf{as}\; id : T_1[r_1, .., r_k] \in e_2 : T_3} \quad \text{T\_UNPACK}$$

$$\frac{}{\Gamma, \Phi, \Omega \vdash id[r_1, .., r_k](e_1, .., e_n) : T} \quad \text{T\_CALL}$$

$$\frac{}{\Gamma, \Phi, \Omega \vdash \{\, \textbf{function}\; id_1\,[r_1, .., r_k]\,(e_1, .., e_m), .., \textbf{function}\; id_n\,[r_1, .., r_k]\,(e_1, .., e_m)\} : T} \quad \text{T\_PROGRAM}$$

$\boxed{M, L, H, S, C \vdash e \mapsto v, E}$ Evaluation

$$\frac{}{M, L, H, S, C \vdash x \mapsto v, E} \quad \textsc{EVa}$$

$$\frac{M, L, H, S, C \vdash e \mapsto l, E}{M, L, H, S, C \vdash \textbf{read}\,(e) \mapsto v, E} \quad \textsc{ERead1}$$

$$\frac{M, L, H, S, C \vdash e \mapsto l, E}{M, L, H, S, C \vdash \textbf{read}\,(e) \mapsto H(l), E} \quad \textsc{ERead2}$$

$$\frac{\begin{array}{c} M, L, H, S, C \vdash e_1 \mapsto l, E_1 \\ M, L, H, S', C \vdash e_2 \mapsto v, E_2 \end{array}}{M, L, H, S, C \vdash \textbf{write}\,(e_1, e_2) \mapsto l, E} \quad \textsc{EWrite}$$

$$\frac{\begin{array}{c} M, L, H, S, C \vdash e_1 \mapsto l, E_1 \\ M, L, H, S', C \vdash e_2 \mapsto v, E_2 \end{array}}{M, L, H, S, C \vdash \textbf{reduce}\,(id, e_1, e_2) \mapsto l, E} \quad \textsc{EReduce}$$

$$\frac{}{M, L, H, S, C \vdash \textbf{null} \mapsto \textbf{null}, []} \quad \textsc{ENull}$$

$$\frac{}{M, L, H, S, C \vdash \textbf{new}\ T@r \mapsto l, []} \quad \textsc{ENew}$$

$$\frac{}{M, L, H, S, C \vdash \textbf{null}\ T@\textbf{nullr} \mapsto \textbf{true}, []} \quad \textsc{ENullTrue}$$

$$\frac{\neg\,(T@r = T@\textbf{nullr})}{M, L, H, S, C \vdash \textbf{null}\ T@r \mapsto \textbf{false}, []} \quad \textsc{ENullFalse}$$

———————————————————— FAKEAAAAAB

<<no parses (char 27): M,L,H,S,C |- e1 |-> l, E1 [***[:prod1value]] >>

$$\frac{l = \textbf{null}}{M, L, H, S, C \vdash \textbf{isnull}\,(l) \mapsto \textbf{true}, []} \quad \textsc{EIsNullTrue}$$

———————————————————— FAKEAAAAAC

<<no parses (char 27): M,L,H,S,C |- e1 |-> l, E1 [***[:prod1value]] >>

$$\frac{\neg\,(l = \textbf{null})}{M, L, H, S, C \vdash \textbf{isnull}\,(l) \mapsto \textbf{false}, []} \quad \textsc{EIsNullFalse}$$

$$\frac{M, L, H, S, C \vdash e \mapsto v, E}{M, L, H, S, C \vdash \textbf{upregion}\,(e, r_1, .., r_n) \mapsto v, E} \quad \textsc{EUpRgn}$$

$$\frac{M, L, H, S, C \vdash e \mapsto v, E}{M, L, H, S, C \vdash \textbf{downregion}\,(e, r_1, .., r_n) \mapsto l, E} \quad \textsc{EDnRgn1}$$

$$\frac{M, L, H, S, C \vdash e \mapsto v, E}{M, L, H, S, C \vdash \textbf{downregion}\,(e, r_1, .., r_n) \mapsto \textbf{null}, E} \quad \textsc{EDnRgn2}$$

$$\frac{\begin{array}{c} M, L, H, S, C \vdash e_1 \mapsto l, E_1 \\ M, L, H, S', C \vdash e_2 \mapsto v, E_2 \\ M, L, H, S'', C \vdash e_3 \mapsto v, E_3 \end{array}}{M, L, H, S, C \vdash \textbf{write}\,(e_1, e_2) \mapsto l, E} \quad \textsc{EColor}$$

$$\frac{\begin{array}{l} M, L, H, S, C \vdash e_1 \mapsto K, E_1 \\ M' = M[\rho_1/r_1, .., \rho_k/r_k] \\ M, L, H, S', C \vdash e_2 \mapsto v, E_2 \end{array}}{M, L, H, S, C \vdash \textbf{partition}\ r_p\ \textbf{using}\ e_1\ \textbf{as}\ r_1, .., r_k\ \in\ e_2 \mapsto l, E'} \quad \textsc{EPartition}$$

$$\frac{M, L, H, S, C \vdash e_1 \mapsto K, E_1}{M, L, H, S, C \vdash \textbf{pack}\ e_1\ \textbf{as}\ T_1[r_1, .., r_k] \mapsto v', E}\ \textsc{EPack}$$

$$\frac{\begin{array}{l} M, L, H, S, C \vdash e_1 \mapsto \langle\langle \rho_1, .., \rho_k, v \rangle\rangle, E_1 \\ M' = M[\rho_1/r_1, .., \rho_k/r_k] \\ L' = L[v_1/id] \\ M', L', H, S', C \vdash e_2 \mapsto v, E_2 \end{array}}{M, L, H, S, C \vdash \textbf{unpack}\ e_1\ \textbf{as}\ id : T_1[r_1, .., r_k] \in e_2 \mapsto v_2, E'}\ \textsc{EUnpack}$$

$$\frac{}{M, L, H, S, C \vdash id[r_1, .., r_k](e_1, .., e_n) \mapsto v_n, E''}\ \textsc{ECall}$$

```
Definition rules:        32 good    2 bad
Definition rule clauses: 70 good    2 bad
```