metavariable, x, xs, y, uf, f, d

term, t, u	::=			term
	|	x		variable
	|	z		value
	|	t u		application
	|	t ; u		pattern-matching on unit
	|	case t of $\{1.x_1 \mapsto u_1, 2.x_2 \mapsto u_2\}$		pattern-matching on sum
	|	case t of $\{\langle x_1, x_2\rangle \mapsto u\}$		pattern-matching on product
	|	case t of { Ur x $\mapsto$ u}		pattern-matching on exponentiated value
	|	case t of $\{\mathsf{roll}_{R}\ x \mapsto u\}$		unroll for recursive types
	|	alloc_{A} d . t		allocate data
	|	t $\triangleleft$ u		fill terminal-type destination
	|	t $\triangleleft$ 1.d′ . u		fill sum-type destination with variant 1
	|	t $\triangleleft$ 2.d′ . u		fill sum-type destination with variant 2
	|	t $\triangleleft$ $\langle d_1, d_2\rangle$. u		fill product-type destination
	|	$\star l$		note: $\star l$ is not a part of the user syntax
	|	(t)	S	
	|	\n sp t \n spe	S	
	|	\n sp t	S	
	|	t[var_subs]	M	
var_sub, vs	::=			variable substitution
	|	x := t		
var_subs	::=			variable substitutions
	|	vs		
	|	vs, var_subs		
data_val, v	::=			data value
	|	()		unit
	|	λ x:A . t		lambda abstraction
	|	Ur t		exponential
	|	roll_{R} t		roll for recursive types
val, z	::=			unreducible value
	|	v		
	|	$\overset{l}{\lfloor A \rfloor}$		note: l is not a part of the user syntax
	|	1.l		
	|	2.l		
	|	$\langle l_1, l_2\rangle$		
	|	C$\bar{l}$	M	
label, l	::=			label
label_stmt, s	::=			label statement
	|	$l \triangleleft$ v		
	|	$l \triangleleft 1.l'$		
	|	$l \triangleleft 2.l'$		
	|	$l \triangleleft \langle l_1, l_2\rangle$		
	|	$l \triangleleft \oslash$		

	|	$l \triangleleft \mathsf{C}\bar{l}$	M	TODO: hide. $l \triangleleft \mathsf{C}\bar{l}$ is an alias for any heap cons
	|	$l \triangleleft \ldots$	M	
label_stmts	::=			label statements
	|	s		
	|	s, label_stmts		
heap_context, $\mathbb{H}$	::=			label statements
	|	$\emptyset$		
	|	{label_stmts}		
	|	$\mathbb{H}_1 \sqcup \mathbb{H}_2$		
type, A, B	::=			
	|	1		unit type
	|	R		recursive type bound to a name
	|	$\mathsf{A} \otimes \mathsf{B}$		product type
	|	$\mathsf{A} \oplus \mathsf{B}$		sum type
	|	$\mathsf{A} \multimap \mathsf{B}$		linear function type
	|	$\lfloor \mathsf{A} \rfloor$		destination type
	|	$!\mathsf{A}$		exponential
	|	(A)	S	
	|	$\mathsf{W}[\mathsf{r} := \mathsf{A}]$	M	
type_with_hole, W	::=			
	|	r		type hole in recursive definition
	|	1		unit type
	|	R		recursive type bound to a name
	|	$\mathsf{W}_1 \otimes \mathsf{W}_2$		product type
	|	$\mathsf{W}_1 \oplus \mathsf{W}_2$		sum type
	|	$\mathsf{W}_1 \multimap \mathsf{W}_2$		linear function type
	|	$\lfloor \mathsf{W} \rfloor$		destination type
	|	$!\mathsf{W}$		exponential
	|	(W)	S	
rec_type_bound, R	::=			recursive type bound to a name
rec_type_def	::=			
	|	$\mu\,\mathsf{r}\,.\,\mathsf{W}$		
type_affect, ta	::=			type affectation
	|	$\mathsf{x} : \mathsf{A}$		var
	|	$l : \mathsf{A}$		label
	|	$\bar{l} : \bar{\mathsf{A}}$		labels
type_affects	::=			type affectations
	|	ta		
	|	ta, type_affects		
typing_context, Γ, Δ, $\mho$, Φ	::=			typing context

	$\mid$	$\emptyset$	
	$\mid$	$\{\mathsf{type\_affects}\}$	
	$\mid$	$\Gamma \sqcup \Delta$	
$\mathsf{types},\ \bar{\mathsf{A}}$	$::=$		
	$\mid$	$\bullet$	empty type list
	$\mid$	A	
	$\mid$	$\mathsf{A}\ \ \mathsf{types}$	
$\mathsf{heap\_constructor},\ \mathsf{C}$	$::=$		
	$\mid$	$(1.)$	
	$\mid$	$(2.)$	
	$\mid$	$(\langle,\rangle)$	
judg	$::=$		
	$\mid$	$\Phi\ ;\ \mho\ ;\ \Gamma \vdash \mathbb{H}$	
	$\mid$	$\Phi\ ;\ \mho\ ;\ \Gamma \vdash \mathbb{H} \mid \mathsf{t} : \mathsf{A}$	
	$\mid$	$\Phi\ ;\ \mho\ ;\ \Gamma \vdash \mathsf{t} : \mathsf{A}$	
	$\mid$	$\mathsf{C} : \bar{\mathsf{A}} \xrightarrow{\mathsf{c}} \mathsf{A}$	
	$\mid$	$\mathsf{A}\ =\ \mathsf{B}$	
	$\mid$	$\mathsf{t}\ =\ \mathsf{u}$	
	$\mid$	$\Gamma\ =\ \Delta$	
	$\mid$	$\mathbb{H} \mid \mathsf{t} \longrightarrow \mathbb{H}' \mid \mathsf{t}'$	
	$\mid$	$\mathsf{type\_affect}\ \in\ \Gamma$	
	$\mid$	$\mathsf{label\_stmt}\ \in\ \mathbb{H}$	
	$\mid$	$\mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset$	
$\mathsf{terminals}$	$::=$		
	$\mid$	$\mapsto$	
	$\mid$	$\star$	
	$\mid$	$\circledast$	
	$\mid$	$\oplus$	
	$\mid$	$\multimap$	
	$\mid$	$:=$	
	$\mid$	$\vdash$	
	$\mid$	$\sqcup$	
	$\mid$	$;$	
	$\mid$	$\cap$	
	$\mid$	$\emptyset$	
	$\mid$	$\longrightarrow$	
	$\mid$	$\triangleright$	
	$\mid$	$\neq$	
	$\mid$	$\in$	
	$\mid$	$\notin$	
	$\mid$	$\backslash\mathsf{n}$	
	$\mid$	$\langle$	
	$\mid$	$\rangle$	
	$\mid$	$1.$	
	$\mid$	$2.$	
	$\mid$	Ur	

	|	$\triangleleft$	
	|	$\mid$	
	|	$\oslash$	
	|	$\overset{c}{\leq}$	
	|	$=$	
	|	$\Downarrow$	
	|	$\ldots$	
	|	$\overset{\mathsf{fix}}{\equiv}$	
formula	::=		
	|	judgement	
Ctx	::=		
	|	$\mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset$	Γ and Δ are disjoint typing contexts with no clashin
	|	type_affect $\in \Gamma$	
Heap	::=		
	|	label_stmt $\in \mathbb{H}$	
Eq	::=		
	|	$\mathsf{A} = \mathsf{B}$	
	|	$\mathsf{t} = \mathsf{u}$	
	|	$\Gamma = \Delta$	
Ty	::=		
	|	$\mathsf{R} \overset{\mathsf{fix}}{\equiv}$ rec_type_def	
	|	$\Phi\ ;\ \mho\ ;\ \Gamma \vdash \mathbb{H}$	$\mathbb{H}$ is a well-typed heap given heap typing context Φ, u
	|	$\Phi\ ;\ \mho\ ;\ \Gamma \vdash \mathbb{H} \mid \mathsf{t} : \mathsf{A}$	
	|	$\Phi\ ;\ \mho\ ;\ \Gamma \vdash \mathsf{t} : \mathsf{A}$	t is a well-typed term of type A given heap typing con
	|	$\mathsf{C} : \bar{\mathsf{A}} \overset{c}{\multimap} \mathsf{A}$	Heap constructor C builds a value of type A given arg
Sem	::=		
	|	$\mathbb{H} \mid \mathsf{t} \longrightarrow \mathbb{H}' \mid \mathsf{t}'$	t reduces to t', with heap changing from $\mathbb{H}$ to $\mathbb{H}'$
	|	$\mathbb{H} \mid \mathsf{t} \ \Downarrow\ \mathbb{H}' \mid \mathsf{t}'$	t reduces to t', with heap growing from $\mathbb{H}$ to $\mathbb{H}'$
judgement	::=		
	|	Ctx	
	|	Heap	
	|	Eq	
	|	Ty	
	|	Sem	
user_syntax	::=		
	|	metavariable	
	|	term	
	|	var_sub	
	|	var_subs	
	|	data_val	
	|	val	

| *label*
| label_stmt
| label_stmts
| heap_context
| type
| type_with_hole
| rec_type_bound
| rec_type_def
| type_affect
| type_affects
| typing_context
| types
| heap_constructor
| judg
| terminals

$\boxed{\mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset}$ Γ and Δ are disjoint typing contexts with no clashing variable names or labels

$\boxed{\mathsf{type\_affect} \in \Gamma}$

$\boxed{\mathsf{label\_stmt} \in \mathbb{H}}$

$\boxed{\mathsf{A} = \mathsf{B}}$

$\boxed{\mathsf{t} = \mathsf{u}}$

$\boxed{\Gamma = \Delta}$

$\boxed{\mathsf{R} \overset{\mathsf{fix}}{=} \mathsf{rec\_type\_def}}$

$\boxed{\Phi \,;\, \mho \,;\, \Gamma \vdash \mathbb{H}}$ $\mathbb{H}$ is a well-typed heap given heap typing context Φ, unrestricted typing context $\mho$ and linear

$$\frac{\begin{array}{l}\Phi_1 \,;\, \mho \,;\, \Gamma \vdash \mathbb{H}_1 \\ \Phi_2 \,;\, \mho \,;\, \Delta \vdash \mathbb{H}_2 \\ \mathsf{names}\,(\Phi_1) \cap \mathsf{names}\,(\Phi_2) = \emptyset \\ \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset\end{array}}{\Phi_1 \sqcup \Phi_2 \,;\, \mho \,;\, \Gamma \sqcup \Delta \vdash \mathbb{H}_1 \sqcup \mathbb{H}_2} \quad \textsc{TyHeap\_Union}$$

$$\frac{\begin{array}{l}\mathsf{C} : \bar{\mathsf{A}} \overset{\mathsf{c}}{\rightharpoonup} \mathsf{A} \\ \Phi \sqcup \{\bar{l} : \bar{\mathsf{A}}\} \,;\, \mho \,;\, \Gamma \vdash \mathbb{H}\end{array}}{\Phi \sqcup \{\bar{l} : \bar{\mathsf{A}}, l : \mathsf{A}\} \,;\, \mho \,;\, \Gamma \vdash \mathbb{H} \sqcup \{l \triangleleft \mathsf{C}\bar{l}\}} \quad \textsc{TyHeap\_Ctor}$$

$$\frac{}{\{l : \mathsf{A}\} \,;\, \mho \,;\, \emptyset \vdash \{l \triangleleft \oslash\}} \quad \textsc{TyHeap\_Null}$$

$$\frac{\Phi \,;\, \mho \,;\, \Gamma \vdash \mathsf{v} : \mathsf{A}}{\Phi \sqcup \{l : \mathsf{A}\} \,;\, \mho \,;\, \Gamma \vdash \mathbb{H} \sqcup \{l \triangleleft \mathsf{v}\}} \quad \textsc{TyHeap\_Val}$$

$\boxed{\Phi \,;\, \mho \,;\, \Gamma \vdash \mathbb{H} \,|\, \mathsf{t} : \mathsf{A}}$

$$\frac{\begin{array}{l}\Phi \,;\, \mho \,;\, \Gamma \vdash \mathbb{H} \\ \Phi \,;\, \mho \,;\, \Delta \vdash \mathsf{t} : \mathsf{A} \\ \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset\end{array}}{\Phi \,;\, \mho \,;\, \Gamma \vdash \mathbb{H} \,|\, \mathsf{t} : \mathsf{A}} \quad \textsc{TyCommand\_Def}$$

$\boxed{\Phi \,;\, \mho \,;\, \Gamma \vdash \mathsf{t} : \mathsf{A}}$ t is a well-typed term of type A given heap typing context Φ, unrestricted typing context

$$\frac{}{\Phi \,;\, \mho \,;\, \{\mathsf{x} : \mathsf{A}\} \vdash \mathsf{x} : \mathsf{A}} \quad \textsc{TyTerm\_Id}$$

$$\frac{}{\Phi\ ;\ \mho \sqcup \{x : A\}\ ;\ \emptyset \vdash x : A}\ \textsc{TyTerm\_Id'}$$

$$\frac{}{\Phi\ ;\ \mho\ ;\ \emptyset \vdash () : 1}\ \textsc{TyTerm\_Unit}$$

$$\frac{\Phi\ ;\ \mho\ ;\ \emptyset \vdash t : A}{\Phi\ ;\ \mho\ ;\ \emptyset \vdash \mathsf{Ur}\ t : !A}\ \textsc{TyTerm\_Exp}$$

$$\frac{}{\Phi\ ;\ \mho\ ;\ \emptyset \vdash \overset{l}{\lfloor A \rfloor} : \lfloor A \rfloor}\ \textsc{TyTerm\_LabelAsDest}$$

$$\frac{}{\Phi \sqcup \{l : A\}\ ;\ \mho\ ;\ \emptyset \vdash \star l : A}\ \textsc{TyTerm\_Deref}$$

$$\frac{C : \bar{A} \overset{c}{\rightharpoonup} A}{\Phi \sqcup \{\bar{l} : \bar{A}\}\ ;\ \mho\ ;\ \emptyset \vdash C\,\bar{l} : A}\ \textsc{TyTerm\_Ctor}$$

$$\frac{\begin{array}{l} R \overset{\text{fix}}{=} \mu\, r\,.\,W \\ \Phi\ ;\ \mho\ ;\ \Gamma \vdash t : W[r := R] \end{array}}{\Phi\ ;\ \mho\ ;\ \Gamma \vdash \underset{R}{\mathsf{roll}}\ t : R}\ \textsc{TyTerm\_Roll}$$

$$\frac{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \{x : A\} \vdash t : B}{\Phi\ ;\ \mho\ ;\ \Gamma \vdash \lambda x{:}A\,.\,t : A \multimap B}\ \textsc{TyTerm\_Lam}$$

$$\frac{\begin{array}{l} \Phi\ ;\ \mho\ ;\ \Gamma \vdash t : A \multimap B \\ \Phi\ ;\ \mho\ ;\ \Delta \vdash u : A \\ \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset \end{array}}{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \Delta \vdash t\,u : B}\ \textsc{TyTerm\_App}$$

$$\frac{\begin{array}{l} \Phi\ ;\ \mho\ ;\ \Gamma \vdash t : 1 \\ \Phi\ ;\ \mho\ ;\ \Delta \vdash u : A \\ \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset \end{array}}{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \Delta \vdash t\ ;\ u : A}\ \textsc{TyTerm\_PatU}$$

$$\frac{\begin{array}{l} \Phi\ ;\ \mho\ ;\ \Gamma \vdash t : A_1 \otimes A_2 \\ \Phi\ ;\ \mho\ ;\ \Delta \sqcup \{x_1 : A_1, x_2 : A_2\} \vdash u : B \\ \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset \end{array}}{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \Delta \vdash \mathsf{case}\ t\ \mathsf{of}\ \{\langle x_1, x_2\rangle \mapsto u\} : B}\ \textsc{TyTerm\_PatP}$$

$$\frac{\begin{array}{l} \Phi\ ;\ \mho\ ;\ \Gamma \vdash t : A_1 \oplus A_2 \\ \Phi\ ;\ \mho\ ;\ \Delta \sqcup \{x_1 : A_1\} \vdash u_1 : B \\ \Phi\ ;\ \mho\ ;\ \Delta \sqcup \{x_2 : A_2\} \vdash u_2 : B \\ \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset \end{array}}{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \Delta \vdash \mathsf{case}\ t\ \mathsf{of}\ \{1.x_1 \mapsto u_1, 2.x_2 \mapsto u_2\} : B}\ \textsc{TyTerm\_PatS}$$

$$\frac{\begin{array}{l} \Phi\ ;\ \mho\ ;\ \Gamma \vdash t : !A \\ \Phi\ ;\ \mho \sqcup \{x : A\}\ ;\ \Delta \vdash u : B \\ \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset \end{array}}{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \Delta \vdash \mathsf{case}\ t\ \mathsf{of}\ \{\,\mathsf{Ur}\ x \mapsto u\} : B}\ \textsc{TyTerm\_PatE}$$

$$\frac{\begin{array}{l} R \overset{\text{fix}}{=} \mu\, r\,.\,W \\ \Phi\ ;\ \mho\ ;\ \Gamma \vdash t : R \\ \Phi\ ;\ \mho\ ;\ \Delta \sqcup \{x : W[r := R]\} \vdash u : B \\ \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset \end{array}}{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \Delta \vdash \mathsf{case}\ t\ \mathsf{of}\ \{\underset{R}{\mathsf{roll}}\ x \mapsto u\} : B}\ \textsc{TyTerm\_PatR}$$

$$\frac{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \{d : \lfloor A \rfloor\} \vdash t : 1}{\Phi\ ;\ \mho\ ;\ \Gamma \vdash \mathsf{alloc}_{A}\ d\,.\,t : A}\ \textsc{TyTerm\_Alloc}$$

$$\frac{\Phi\ ;\ \mho\ ;\ \Gamma \vdash t : \lfloor A \rfloor \quad \Phi\ ;\ \mho\ ;\ \Delta \vdash u : A \quad \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset}{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \Delta \vdash t \triangleleft u : 1}\ \textsc{TyTerm\_FillL}$$

$$\frac{\Phi\ ;\ \mho\ ;\ \Gamma \vdash t : \lfloor A_1 \oplus A_2 \rfloor \quad \Phi\ ;\ \mho\ ;\ \Delta \sqcup \{d' : \lfloor A_1 \rfloor\} \vdash u : B \quad \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset}{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \Delta \vdash t \triangleleft 1.d'\,.\,u : B}\ \textsc{TyTerm\_FillV1}$$

$$\frac{\Phi\ ;\ \mho\ ;\ \Gamma \vdash t : \lfloor A_1 \oplus A_2 \rfloor \quad \Phi\ ;\ \mho\ ;\ \Delta \sqcup \{d' : \lfloor A_2 \rfloor\} \vdash u : B \quad \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset}{\Phi\ ;\ \mho\ ;\ \Gamma \vdash t \triangleleft 2.d'\,.\,u : B}\ \textsc{TyTerm\_FillV2}$$

$$\frac{\Phi\ ;\ \mho\ ;\ \Gamma \vdash t : \lfloor A_1 \otimes A_2 \rfloor \quad \Phi\ ;\ \mho\ ;\ \Delta \sqcup \{d_1 : \lfloor A_1 \rfloor, d_2 : \lfloor A_2 \rfloor\} \vdash u : B \quad \mathsf{names}\,(\Gamma) \cap \mathsf{names}\,(\Delta) = \emptyset}{\Phi\ ;\ \mho\ ;\ \Gamma \sqcup \Delta \vdash t \triangleleft \langle d_1, d_2 \rangle\,.\,u : B}\ \textsc{TyTerm\_FillP}$$

$\boxed{C : \bar{A} \xrightarrow{c} A}$ Heap constructor C builds a value of type A given arguments of type $\bar{A}$

$$\frac{}{(1.) : A \xrightarrow{c} A \oplus B}\ \textsc{TyCtor\_V1}$$

$$\frac{}{(2.) : B \xrightarrow{c} A \oplus B}\ \textsc{TyCtor\_V2}$$

$$\frac{}{(\langle , \rangle) : A\ \ B \xrightarrow{c} A \otimes B}\ \textsc{TyCtor\_Pair}$$

$\boxed{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}$ t reduces to t', with heap changing from $\mathbb{H}$ to $\mathbb{H}'$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid t\,u \longrightarrow \mathbb{H}' \mid t'\,u}\ \textsc{SemMut\_uApp}$$

$$\frac{}{\mathbb{H} \mid (\lambda x{:}A\,.\,t)\,u \longrightarrow \mathbb{H} \mid t[x := u]}\ \textsc{SemMut\_App}$$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid t\ ;\ u \longrightarrow \mathbb{H}' \mid t'\ ;\ u}\ \textsc{SemMut\_uPatU}$$

$$\frac{}{\mathbb{H} \mid ()\ ;\ u \longrightarrow \mathbb{H} \mid u}\ \textsc{SemMut\_PatU}$$

$$\frac{}{\mathbb{H} \sqcup \{l \triangleleft v\} \mid \star l \longrightarrow \mathbb{H} \sqcup \{l \triangleleft v\} \mid v}\ \textsc{SemMut\_DerefVal}$$

$$\frac{}{\mathbb{H} \sqcup \{l \triangleleft C\bar{l}\} \mid \star l \longrightarrow \mathbb{H} \sqcup \{l \triangleleft C\bar{l}\} \mid C\bar{l}}\ \textsc{SemMut\_DerefCtor}$$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid \mathsf{case}\,t\,\mathsf{of}\,\{1.x_1 \mapsto u_1, 2.x_2 \mapsto u_2\} \longrightarrow \mathbb{H}' \mid \mathsf{case}\,t'\,\mathsf{of}\,\{1.x_1 \mapsto u_1, 2.x_2 \mapsto u_2\}}\ \textsc{SemMut\_uPatS}$$

$$\frac{}{\mathbb{H} \mid \mathsf{case}\,1.l\,\mathsf{of}\,\{1.x_1 \mapsto u_1, 2.x_2 \mapsto u_2\} \longrightarrow \mathbb{H} \mid u_1[x_1 := \star l]}\ \textsc{SemMut\_PatSV1}$$

$$\frac{}{\mathbb{H} \mid \mathsf{case}\,2.l\,\mathsf{of}\,\{1.x_1 \mapsto u_1, 2.x_2 \mapsto u_2\} \longrightarrow \mathbb{H} \mid u_2[x_2 := \star l]}\ \textsc{SemMut\_PatSV2}$$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid \mathsf{case}\ t\ \mathsf{of}\ \{\langle x_1, x_2\rangle \mapsto u\} \longrightarrow \mathbb{H}' \mid \mathsf{case}\ t'\ \mathsf{of}\ \{\langle x_1, x_2\rangle \mapsto u\}}\ \textsc{SemMut\_uPatP}$$

$$\frac{}{\mathbb{H} \mid \mathsf{case}\ \langle l_1, l_2\rangle\ \mathsf{of}\ \{\langle x_1, x_2\rangle \mapsto u\} \longrightarrow \mathbb{H} \mid u[x_1 := \star l_1, x_2 := \star l_2]}\ \textsc{SemMut\_PatP}$$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid \mathsf{case}\ t\ \mathsf{of}\ \{\ \mathsf{Ur}\ x \mapsto u\} \longrightarrow \mathbb{H}' \mid \mathsf{case}\ t'\ \mathsf{of}\ \{\ \mathsf{Ur}\ x \mapsto u\}}\ \textsc{SemMut\_uPatE}$$

$$\frac{}{\mathbb{H} \mid \mathsf{case}\ \mathsf{Ur}\ t\ \mathsf{of}\ \{\ \mathsf{Ur}\ x \mapsto u\} \longrightarrow \mathbb{H} \mid u[x := t]}\ \textsc{SemMut\_PatE}$$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid \mathsf{case}\ t\ \mathsf{of}\ \{\underset{R}{\mathsf{roll}}\ x \mapsto u\} \longrightarrow \mathbb{H}' \mid \mathsf{case}\ t'\ \mathsf{of}\ \{\underset{R}{\mathsf{roll}}\ x \mapsto u\}}\ \textsc{SemMut\_uPatR}$$

$$\frac{}{\mathbb{H} \mid \mathsf{case}\ \underset{R}{\mathsf{roll}}\ t\ \mathsf{of}\ \{\underset{R}{\mathsf{roll}}\ x \mapsto u\} \longrightarrow \mathbb{H} \mid u[x := t]}\ \textsc{SemMut\_PatR}$$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid t \lhd u \longrightarrow \mathbb{H}' \mid t' \lhd u}\ \textsc{SemMut\_uFillL}$$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid \overset{l}{\lfloor A \rfloor} \lhd t \longrightarrow \mathbb{H}' \mid \overset{l}{\lfloor A \rfloor} \lhd t'}\ \textsc{SemMut\_uFillL'}$$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid t \lhd 1.d' \,.\, u \longrightarrow \mathbb{H}' \mid t' \lhd 1.d' \,.\, u}\ \textsc{SemMut\_uFillV1}$$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid t \lhd 2.d' \,.\, u \longrightarrow \mathbb{H}' \mid t' \lhd 2.d' \,.\, u}\ \textsc{SemMut\_uFillV2}$$

$$\frac{\mathbb{H} \mid t \longrightarrow \mathbb{H}' \mid t'}{\mathbb{H} \mid t \lhd \langle d_1, d_2\rangle \,.\, u \longrightarrow \mathbb{H}' \mid t' \lhd \langle d_1, d_2\rangle \,.\, u}\ \textsc{SemMut\_uFillP}$$

$$\frac{}{\mathbb{H} \mid \underset{A}{\mathsf{alloc}}\ d \,.\, t \longrightarrow \mathbb{H} \sqcup \{l \lhd \oslash\} \mid t[d := \overset{l}{\lfloor A \rfloor}]\ ;\ \star l}\ \textsc{SemMut\_Alloc}$$

$$\frac{}{\mathbb{H} \sqcup \{l \lhd \oslash\} \mid \overset{l}{\lfloor A \rfloor} \lhd v \longrightarrow \mathbb{H} \sqcup \{l \lhd v\} \mid ()}\ \textsc{SemMut\_FillLV}$$

$$\frac{}{\mathbb{H} \sqcup \{l \lhd \oslash\} \mid \overset{l}{\lfloor A \rfloor} \lhd C\bar{l} \longrightarrow \mathbb{H} \sqcup \{l \lhd C\bar{l}\} \mid ()}\ \textsc{SemMut\_FillLCtor}$$

$$\frac{}{\mathbb{H} \sqcup \{l \lhd \oslash\} \mid \overset{l}{\lfloor A_1 \oplus A_2 \rfloor} \lhd 1.d' \,.\, t \longrightarrow \mathbb{H} \sqcup \{l \lhd 1.l', l' \lhd \oslash\} \mid t[d' := \overset{l'}{\lfloor A_1 \rfloor}]}\ \textsc{SemMut\_FillV1}$$

$$\frac{}{\mathbb{H} \sqcup \{l \lhd \oslash\} \mid \overset{l}{\lfloor A_1 \oplus A_2 \rfloor} \lhd 2.d' \,.\, t \longrightarrow \mathbb{H} \sqcup \{l \lhd 2.l', l' \lhd \oslash\} \mid t[d' := \overset{l'}{\lfloor A_2 \rfloor}]}\ \textsc{SemMut\_FillV2}$$

$$\frac{}{\mathbb{H} \sqcup \{l \lhd \oslash\} \mid \overset{l}{\lfloor A_1 \otimes A_2 \rfloor} \lhd \langle d_1, d_2\rangle \,.\, t \longrightarrow \mathbb{H} \sqcup \{l \lhd \langle l_1, l_2\rangle, l_1 \lhd \oslash, l_2 \lhd \oslash\} \mid t[d_1 := \overset{l_1}{\lfloor A_1 \rfloor}, d_2 := \overset{l_2}{\lfloor A_2 \rfloor}]}\ \textsc{SemMut\_FillP}$$

$\boxed{\mathbb{H} \mid t \ \Downarrow\ \mathbb{H}' \mid t'}$ t reduces to t', with heap growing from $\mathbb{H}$ to $\mathbb{H}'$

$$\frac{}{\mathbb{H} \mid \underset{R}{\mathsf{roll}}\ t \ \Downarrow\ \mathbb{H} \mid t}\ \textsc{SemImm\_Roll}$$

$$\frac{\mathbb{H} \mid t \ \Downarrow\ \mathbb{H}' \mid t'}{\mathbb{H} \mid t\ u \ \Downarrow\ \mathbb{H}' \mid t'\ u}\ \textsc{SemImm\_uApp}$$

$$\frac{}{\mathbb{H} \mid (\lambda x{:}A \,.\, t)\ u \ \Downarrow\ \mathbb{H} \mid t[x := u]}\ \textsc{SemImm\_App}$$

$$\frac{\mathbb{H} \mid t \;\Downarrow\; \mathbb{H}' \mid t'}{\mathbb{H} \mid t \,;\, u \;\Downarrow\; \mathbb{H}' \mid t' \,;\, u}\ \textsc{SemImm\_uPatU}$$

$$\frac{}{\mathbb{H} \mid () \,;\, u \;\Downarrow\; \mathbb{H} \mid u}\ \textsc{SemImm\_PatU}$$

$$\frac{}{\mathbb{H} \sqcup \{l \triangleleft v\} \mid \star l \;\Downarrow\; \mathbb{H} \sqcup \{l \triangleleft v\} \mid v}\ \textsc{SemImm\_DerefVal}$$

$$\frac{}{\mathbb{H} \sqcup \{l \triangleleft \mathsf{C}\,\overline{l}\} \mid \star l \;\Downarrow\; \mathbb{H} \sqcup \{l \triangleleft \mathsf{C}\,\overline{l}\} \mid \mathsf{C}\,\overline{l}}\ \textsc{SemImm\_DerefCtor}$$

$$\frac{\mathbb{H} \mid t \;\Downarrow\; \mathbb{H}' \mid t'}{\mathbb{H} \mid \mathsf{case}\ t\ \mathsf{of}\ \{1.x_1 \mapsto u_1, 2.x_2 \mapsto u_2\} \;\Downarrow\; \mathbb{H}' \mid \mathsf{case}\ t'\ \mathsf{of}\ \{1.x_1 \mapsto u_1, 2.x_2 \mapsto u_2\}}\ \textsc{SemImm\_uPatS}$$

$$\frac{}{\mathbb{H} \mid \mathsf{case}\ 1.l\ \mathsf{of}\ \{1.x_1 \mapsto u_1, 2.x_2 \mapsto u_2\} \;\Downarrow\; \mathbb{H} \mid u_1[x_1 := \star l]}\ \textsc{SemImm\_PatSV1}$$

$$\frac{}{\mathbb{H} \mid \mathsf{case}\ 2.l\ \mathsf{of}\ \{1.x_1 \mapsto u_1, 2.x_2 \mapsto u_2\} \;\Downarrow\; \mathbb{H} \mid u_2[x_2 := \star l]}\ \textsc{SemImm\_PatSV2}$$

$$\frac{\mathbb{H} \mid t \;\Downarrow\; \mathbb{H}' \mid t'}{\mathbb{H} \mid \mathsf{case}\ t\ \mathsf{of}\ \{\langle x_1, x_2\rangle \mapsto u\} \;\Downarrow\; \mathbb{H}' \mid \mathsf{case}\ t'\ \mathsf{of}\ \{\langle x_1, x_2\rangle \mapsto u\}}\ \textsc{SemImm\_uPatP}$$

$$\frac{}{\mathbb{H} \mid \mathsf{case}\ \langle l_1, l_2\rangle\ \mathsf{of}\ \{\langle x_1, x_2\rangle \mapsto u\} \;\Downarrow\; \mathbb{H} \mid u[x_1 := \star l_1, x_2 := \star l_2]}\ \textsc{SemImm\_PatP}$$

$$\frac{\mathbb{H} \mid t \;\Downarrow\; \mathbb{H}' \mid t'}{\mathbb{H} \mid \mathsf{case}\ t\ \mathsf{of}\ \{\ \mathsf{Ur}\ x \mapsto u\} \;\Downarrow\; \mathbb{H}' \mid \mathsf{case}\ t'\ \mathsf{of}\ \{\ \mathsf{Ur}\ x \mapsto u\}}\ \textsc{SemImm\_uPatE}$$

$$\frac{}{\mathbb{H} \mid \mathsf{case}\ \mathsf{Ur}\ t\ \mathsf{of}\ \{\ \mathsf{Ur}\ x \mapsto u\} \;\Downarrow\; \mathbb{H} \mid u[x := t]}\ \textsc{SemImm\_PatE}$$

$$\frac{\mathbb{H} \mid t \;\Downarrow\; \mathbb{H}' \mid t'}{\mathbb{H} \mid \mathsf{case}\ t\ \mathsf{of}\ \{\underset{R}{\mathsf{roll}}\ x \mapsto u\} \;\Downarrow\; \mathbb{H}' \mid \mathsf{case}\ t'\ \mathsf{of}\ \{\underset{R}{\mathsf{roll}}\ x \mapsto u\}}\ \textsc{SemImm\_uPatR}$$

$$\frac{}{\mathbb{H} \mid \mathsf{case}\ \underset{R}{\mathsf{roll}}\ t\ \mathsf{of}\ \{\underset{R}{\mathsf{roll}}\ x \mapsto u\} \;\Downarrow\; \mathbb{H} \mid u[x := t]}\ \textsc{SemImm\_PatR}$$

$$\frac{\mathbb{H} \mid t \;\Downarrow\; \mathbb{H}' \mid t'}{\mathbb{H} \mid t \triangleleft u \;\Downarrow\; \mathbb{H}' \mid t' \triangleleft u}\ \textsc{SemImm\_uFillL}$$

$$\frac{\mathbb{H} \mid t \;\Downarrow\; \mathbb{H}' \mid t'}{\mathbb{H} \mid \overset{l}{\lfloor A \rfloor} \triangleleft t \;\Downarrow\; \mathbb{H}' \mid \overset{l}{\lfloor A \rfloor} \triangleleft t'}\ \textsc{SemImm\_uFillL'}$$

$$\frac{\mathbb{H} \mid t \;\Downarrow\; \mathbb{H}' \mid t'}{\mathbb{H} \mid t \triangleleft 1.d' \,.\, u \;\Downarrow\; \mathbb{H}' \mid t' \triangleleft 1.d' \,.\, u}\ \textsc{SemImm\_uFillV1}$$

$$\frac{\mathbb{H} \mid t \;\Downarrow\; \mathbb{H}' \mid t'}{\mathbb{H} \mid t \triangleleft 2.d' \,.\, u \;\Downarrow\; \mathbb{H}' \mid t' \triangleleft 2.d' \,.\, u}\ \textsc{SemImm\_uFillV2}$$

$$\frac{\mathbb{H} \mid t \;\Downarrow\; \mathbb{H}' \mid t'}{\mathbb{H} \mid t \triangleleft \langle d_1, d_2\rangle \,.\, u \;\Downarrow\; \mathbb{H}' \mid t' \triangleleft \langle d_1, d_2\rangle \,.\, u}\ \textsc{SemImm\_uFillP}$$

$$\frac{\mathbb{H} \mid t[d := \overset{l}{\lfloor A \rfloor}] \;\Downarrow\; \mathbb{H}' \sqcup \{l \triangleleft \ldots\} \mid ()}{\mathbb{H} \mid \underset{A}{\mathsf{alloc}}\ d \,.\, t \;\Downarrow\; \mathbb{H}' \sqcup \{l \triangleleft \ldots\} \mid \star l}\ \textsc{SemImm\_Alloc} \quad \text{— } \textit{Changes start from there} \text{ —}$$

$$\frac{}{\mathbb{H} \mid \overset{l}{\lfloor A \rfloor} \triangleleft v \;\Downarrow\; \mathbb{H} \sqcup \{l \triangleleft v\} \mid ()}\ \textsc{SemImm\_FillLV}$$

$$\frac{}{\mathbb{H} \mid \overset{l}{\lfloor A \rfloor} \triangleleft \mathsf{C}\,\overline{l} \;\Downarrow\; \mathbb{H} \sqcup \{l \triangleleft \mathsf{C}\,\overline{l}\} \mid ()}\ \textsc{SemImm\_FillLCtor}$$

$$\frac{\mathbb{H} \mid \mathtt{t}[\mathsf{d}' := {}^{l'}_{\lfloor \mathsf{A}_1 \rfloor}] \;\Downarrow\; \mathbb{H}' \sqcup \{ l' \triangleleft \ldots \} \mid ()}{\mathbb{H} \mid {}^{l}_{\lfloor \mathsf{A}_1 \oplus \mathsf{A}_2 \rfloor} \triangleleft 1.\mathsf{d}' \,\boldsymbol{.}\, \mathtt{t} \;\Downarrow\; \mathbb{H}' \sqcup \{ l' \triangleleft \ldots, l \triangleleft 1.l' \} \mid ()} \quad \textsc{SemImm\_FillV1}$$

$$\frac{\mathbb{H} \mid \mathtt{t}[\mathsf{d}' := {}^{l'}_{\lfloor \mathsf{A}_2 \rfloor}] \;\Downarrow\; \mathbb{H}' \sqcup \{ l' \triangleleft \ldots \} \mid ()}{\mathbb{H} \mid {}^{l}_{\lfloor \mathsf{A}_1 \oplus \mathsf{A}_2 \rfloor} \triangleleft 2.\mathsf{d}' \,\boldsymbol{.}\, \mathtt{t} \;\Downarrow\; \mathbb{H}' \sqcup \{ l' \triangleleft \ldots, l \triangleleft 2.l' \} \mid ()} \quad \textsc{SemImm\_FillV2}$$

$$\frac{\mathbb{H} \mid \mathtt{t}[\mathsf{d}_1 := {}^{l_1}_{\lfloor \mathsf{A}_1 \rfloor}, \mathsf{d}_2 := {}^{l_2}_{\lfloor \mathsf{A}_2 \rfloor}] \;\Downarrow\; \mathbb{H}' \sqcup \{ l_1 \triangleleft \ldots, l_2 \triangleleft \ldots \} \mid ()}{\mathbb{H} \sqcup \{ l \triangleleft \oslash \} \mid {}^{l}_{\lfloor \mathsf{A}_1 \otimes \mathsf{A}_2 \rfloor} \triangleleft \langle \mathsf{d}_1, \mathsf{d}_2 \rangle \,\boldsymbol{.}\, \mathtt{t} \;\Downarrow\; \mathbb{H}' \sqcup \{ l_1 \triangleleft \ldots, l_2 \triangleleft \ldots, l \triangleleft \langle l_1, l_2 \rangle \} \mid ()} \quad \textsc{SemImm\_FillP}$$

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Definition rules:         81 good    0 bad
Definition rule clauses: 155 good    0 bad
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