`programs`	P	$::=$	$\texttt{def}\ A.m :: \tau_m\ =\ e \mid P;P$
`values`	v	$::=$	$\texttt{nil} \mid [A] \mid \tau_b$
`expressions`	e	$::=$	$v \mid x \mid \texttt{self} \mid x = e \mid e;e$
		$\mid$	$A.\texttt{new} \mid \texttt{if}\ e\ \texttt{then}\ e\ \texttt{else}\ e$
		$\mid$	$e.m(e) \mid f \mid f = e$
`base types`	τ_b	$::=$	$A \mid \texttt{tnil}$
`types`	τ	$::=$	$\tau_b \mid \Pi x.e$
`mth types`	τ_m	$::=$	$\tau \rightarrow \tau :: \varphi$

$x \in$ var ids, $f \in$ field ids, $m \in$ meth ids, $A \in$ class ids, and $\texttt{Type} \in A$

`typ env`	Γ	$::=$	ids $\rightarrow$ types
`heap`	$\mathcal{H}$	$::=$	locs $\rightarrow$ obj. records
`effects`	φ	$::=$	$\texttt{PURE} \mid \texttt{IMPURE}$

MK:♣ Should types be their own kind of value? Or are they also just instances of a class A?♣

MK:♣ Do we want more kinds of types than just nominal types A? The interesting computations involve other types.♣

MK:♣ Is a self binding necessary within type computations? Both for evaluating and type checking it?♣

MK:♣ Can the TIf rule use unions of types if types are just defined as A/nil?♣

MK:♣ TAppBase rule: is this correct? Specifically type/effect checking of method body. Related: should effects be part of method annotation?♣

Type checking rules $\boxed{\Gamma \vdash e : \tau \ \&\ \varphi}$

$$\frac{}{\Gamma \vdash \texttt{nil} : \texttt{tnil} \ \&\ \texttt{PURE}}\ \text{TNil} \qquad \frac{}{\Gamma \vdash [A] : A \ \&\ \texttt{PURE}}\ \text{TObject} \qquad \frac{}{\Gamma \vdash \tau_b : \texttt{Type} \ \&\ \texttt{PURE}}\ \text{TType}$$

$$\frac{}{\Gamma \vdash x : \Gamma(x) \ \&\ \texttt{PURE}}\ \text{TVar} \qquad \frac{}{\Gamma \vdash \texttt{self} : \Gamma(\texttt{self}) \ \&\ \texttt{PURE}}\ \text{TSelf} \qquad \frac{\Gamma(x) = \tau_{b1} \quad \Gamma \vdash e : \tau_{b2} \ \&\ \varphi \quad \tau_{b2} \leq \tau_{b1}}{\Gamma \vdash x = e : \tau_{b2} \ \&\ \varphi}\ \text{TAssn}$$

$$\frac{\Gamma \vdash e_1 : \tau_{b1} \ \&\ \varphi_1 \quad \Gamma_1 \vdash e_2 : \tau_{b2} \ \&\ \varphi_2}{\Gamma \vdash e_1; e_2 : \tau_{b2} \ \&\ (\varphi_1 \sqcup \varphi_2)}\ \text{TSeq} \qquad \frac{}{\Gamma \vdash A.\texttt{new} : A \ \&\ \texttt{PURE}}\ \text{TNew}$$

$$\frac{\Gamma \vdash e_1 : \tau_{b1} \ \&\ \varphi_1 \quad \Gamma \vdash e_2 : \tau_{b2} \ \&\ \varphi_2 \quad \Gamma \vdash e_3 : \tau_{b3} \ \&\ \varphi_3}{\Gamma \vdash \texttt{if } e_1 \texttt{ then } e_2 \texttt{ else } e_3 : (\tau_{b2} \sqcup \tau_{b3}) \ \&\ (\varphi_1 \sqcup \varphi_2 \sqcup \varphi_3)}\ \text{TIf}$$

$$\frac{\Gamma(self) = A \quad \Gamma(A.f) = \tau_b \quad \Gamma \vdash e : \tau_{b1} \ \&\ \varphi \quad \tau_{b1} \leq \tau_b}{\Gamma \vdash f = e : \tau_{b1} \ \&\ \texttt{IMPURE}}\ \text{TFAssn} \qquad \frac{\Gamma(self) = A}{\Gamma \vdash f : \Gamma(A.f) \ \&\ \textit{I think impure?}}\ \text{TFVar}$$

$$\frac{\Gamma \vdash e_0 : A \ \&\ \varphi_1 \quad \Gamma \vdash e_1 : \tau_b \ \&\ \varphi_2 \quad \Gamma(A.m) = \tau_{b1} \to \tau_{b2} :: \varphi_3 \quad \tau_b \leq \tau_{b1}}{\Gamma \vdash e_0.m(e_1) : \tau_{b2} \ \&\ \varphi_1 \sqcup \varphi_2 \sqcup \varphi_3}\ \text{TAppBase}$$

$$\frac{\begin{array}{c}\Gamma \vdash e_0 : A \ \&\ \varphi_1 \qquad \Gamma \vdash e_1 : \tau_b \ \&\ \varphi_2 \\ \Gamma(A.m) = \Pi x.e_{t1} \to \Pi x.e_{t2} :: \varphi_3 \\ \Gamma \vdash e_{t1}[x \mapsto \tau_b] : \texttt{Type} \ \&\ \texttt{PURE} \quad \Gamma \vdash e_{t2}[x \mapsto \tau_b] : \texttt{Type} \ \&\ \texttt{PURE} \\ e_{t1}[x \mapsto \tau_b] \leadsto \tau_{b1} \qquad e_{t2}[x \mapsto \tau_b] \leadsto \tau_{b2} \qquad \tau_b \leq \tau_{b1} \\ \text{type checking above terminates}\end{array}}{\Gamma \vdash e_0.m(e_1) : \tau_{b2} \ \&\ \varphi_1 \sqcup \varphi_2 \sqcup \varphi_3}\ \text{TAppComp}$$

$$\frac{\begin{array}{c}\Gamma \vdash e_0 : A \ \&\ \varphi_1 \qquad \Gamma \vdash e_1 : \tau_b \ \&\ \varphi_2 \\ \Gamma(A.m) = \Pi x.e_{t1} \to \tau_{b2} :: \varphi_3 \quad \Gamma \vdash e_{t1}[x \mapsto \tau_b] : \texttt{Type} \ \&\ \texttt{PURE} \\ e_{t1}[x \mapsto \tau_b] \leadsto \tau_{b1} \qquad \tau_b \leq \tau_{b1} \\ \text{type checking above terminates}\end{array}}{\Gamma \vdash e_0.m(e_1) : \tau_{b2} \ \&\ \varphi_1 \sqcup \varphi_2 \sqcup \varphi_3}\ \text{TAppArg}$$

$$\frac{\begin{array}{c}\Gamma \vdash e_0 : A \ \&\ \varphi_1 \qquad \Gamma \vdash e_1 : \tau_b \ \&\ \varphi_2 \\ \Gamma(A.m) = \tau_{b1} \to \Pi x.e_{t2} :: \varphi_3 \qquad \tau_b \leq \tau_{b1} \\ \Gamma \vdash e_{t2}[x \mapsto \tau_b] : \texttt{Type} \ \&\ \texttt{PURE} \quad e_{t2}[x \mapsto \tau_b] \leadsto \tau_{b2} \\ \text{type checking above terminates}\end{array}}{\Gamma \vdash e_0.m(e_1) : \tau_{b2} \ \&\ \varphi_1 \sqcup \varphi_2 \sqcup \varphi_3}\ \text{TAppRet}$$

Dynamic semantics $\boxed{e \rightsquigarrow e'}$