

<i>n, i, j, k</i>	Index variables for meta-lists
<i>num</i>	Numeric literals
<i>nat</i>	Internal literal numbers
<i>hex</i>	Bit vector literal, specified by C-style hex number
<i>bin</i>	Bit vector literal, specified by C-style binary number
<i>string</i>	String literals
<i>backtick_string</i>	String literals
<i>regex</i>	Regular expressions, as a string literal
<i>x, y, z</i>	Variables
<i>ix</i>	Variables

$l$	$::=$ 	Source locations
$x^l, y^l, z^l, name$	$::=$   $x\ l$   $(ix)l$   $name\_t \rightarrow x^l$	Location-annotated names  Remove infix status M Extract x from a name_t
$ix^l$	$::=$   $ix\ l$	Location-annotated infix names
$\alpha$	$::=$   $'x$	Type variables
$\alpha^l$	$::=$   $\alpha\ l$	Location-annotated type variables
$N$	$::=$   $''x$	numeric variables
$N^l$	$::=$   $N\ l$	Location-annotated numeric variables
$id$	$::=$   $x_1^l \dots x_n^l . x^l\ l$	Long identifiers
$tnv$	$::=$   $\alpha$   $N$	Union of type variables and Nexp type variables, without loc
$tnvar^l$	$::=$   $\alpha^l$   $N^l$	Union of type variables and Nexp type variables, with locati
$tnvs$	$::=$   $tnv_1 .. tnv_n$	Type variable lists
$tnvars^l$	$::=$   $tnvar_1^l .. tnvar_n^l$	Type variable lists
$Nexp\_aux$	$::=$   $N$   $num$   $Nexp_1 * Nexp_2$   $Nexp_1 + Nexp_2$   $(Nexp)$	Numerical expressions for specifying vector lengths and inde

$Nexp$	$::=$ $  \quad Nexp\_aux \ l$	Location-annotated vector lengths
$Nexp\_constraint\_aux$	$::=$ $  \quad Nexp = Nexp'$ $  \quad Nexp \geq Nexp'$	Whether a vector is bounded or fixed size
$Nexp\_constraint$	$::=$ $  \quad Nexp\_constraint\_aux \ l$	Location-annotated Nexp range
$typ\_aux$	$::=$ $  \quad -$ $  \quad \alpha^l$ $  \quad typ_1 \rightarrow typ_2$ $  \quad typ_1 * \dots * typ_n$ $  \quad Nexp$ $  \quad id \ typ_1 .. typ_n$ $  \quad backtick\_string \ typ_1 .. typ_n$ $  \quad (typ)$	Types Unspecified type Type variables Function types Tuple types As a typ to permit applications over Nexps, or Type applications Backend-Type applications
$typ$	$::=$ $  \quad typ\_aux \ l$	Location-annotated types
$lit\_aux$	$::=$ $  \quad \mathbf{true}$ $  \quad \mathbf{false}$ $  \quad num$ $  \quad hex$ $  \quad bin$ $  \quad string$ $  \quad ()$ $  \quad \mathbf{bitzero}$ $  \quad \mathbf{bitone}$	Literal constants  hex and bin are constant bit vectors, entered as  bitzero and bitone are constant bits, if common
$lit$	$::=$ $  \quad lit\_aux \ l$	Location-annotated literal constants
$;\text{?}$	$::=$ $ $ $  \quad ;$	Optional semi-colons
$pat\_aux$	$::=$ $  \quad -$ $  \quad (pat \ \mathbf{as} \ x^l)$ $  \quad (pat : typ)$ $  \quad id \ pat_1 .. pat_n$ $  \quad \langle   fpat_1; \dots; fpat_n; ?   \rangle$	Patterns Wildcards Named patterns Typed patterns Single variable and constructor patterns Record patterns

		$[ pat_1; \dots; pat_n; ? ]$	Vector patterns
		$[ pat_1 .. pat_n ]$	Concatenated vector patterns
		$(pat_1, \dots, pat_n)$	Tuple patterns
		$[pat_1; \dots; pat_n; ?]$	List patterns
		$(pat)$	
		$pat_1 :: pat_2$	Cons patterns
		$x^l + num$	constant addition patterns
		$lit$	Literal constant patterns
$pat$	$::=$		Location-annotated patterns
		$pat\_aux\ l$	
$fpat$	$::=$		Field patterns
		$id = pat\ l$	
$ ^?$	$::=$		Optional bars
$exp\_aux$	$::=$		Expressions
		$id$	Identifiers
		$backtick\_string$	identifier that should be literally used in output
		$N$	Nexp var, has type num
		<b>fun</b> $psexp$	Curried functions
		<b>function</b> $ ^? pexp_1  \dots  pexp_n$ <b>end</b>	Functions with pattern matching
		$exp_1\ exp_2$	Function applications
		$exp_1\ ix^l\ exp_2$	Infix applications
		$\langle  fexps  \rangle$	Records
		$\langle  exp\ \mathbf{with}\ fexps  \rangle$	Functional update for records
		$exp.id$	Field projection for records
		$[ exp_1; \dots; exp_n; ? ]$	Vector instantiation
		$exp.(Nexp)$	Vector access
		$exp.(Nexp_1..Nexp_2)$	Subvector extraction
		<b>match</b> $exp\ \mathbf{with}$ $ ^? pexp_1  \dots  pexp_n\ l$ <b>end</b>	Pattern matching expressions
		$(exp : typ)$	Type-annotated expressions
		<b>let</b> $letbind\ \mathbf{in}\ exp$	Let expressions
		$(exp_1, \dots, exp_n)$	Tuples
		$[exp_1; \dots; exp_n; ?]$	Lists
		$(exp)$	
		<b>begin</b> $exp$ <b>end</b>	Alternate syntax for $(exp)$
		<b>if</b> $exp_1$ <b>then</b> $exp_2$ <b>else</b> $exp_3$	Conditionals
		$exp_1 :: exp_2$	Cons expressions
		$lit$	Literal constants
		$\{exp_1 exp_2\}$	Set comprehensions
		$\{exp_1  \mathbf{forall}\ qbind_1 .. qbind_n exp_2\}$	Set comprehensions with explicit binding
		$\{exp_1; \dots; exp_n; ?\}$	Sets
		$q\ qbind_1 \dots qbind_n.exp$	Logical quantifications

		$[exp_1   \mathbf{forall} \ qbind_1 .. qbind_n   exp_2]$	List comprehensions (all binders must be $\mathbf{forall}$ )
		$\mathbf{do} \ id \ pat_1 \leftarrow exp_1; .. pat_n \leftarrow exp_n; \mathbf{in} \ exp \mathbf{end}$	Do notation for monads
$exp$	$::=$	$exp\_aux \ l$	Location-annotated expressions
$q$	$::=$	$\mathbf{forall}$	Quantifiers
		$\mathbf{exists}$	
$qbind$	$::=$	$x^l$	Bindings for quantifiers
		$(pat \mathbf{IN} \ exp)$	Restricted quantifications over sets
		$(pat \mathbf{MEM} \ exp)$	Restricted quantifications over lists
$fexp$	$::=$	$id = exp \ l$	Field-expressions
$fexps$	$::=$	$fexp_1; ...; fexp_n; ? \ l$	Field-expression lists
$pexp$	$::=$	$pat \rightarrow exp \ l$	Pattern matches
$psexp$	$::=$	$pat_1 ... pat_n \rightarrow exp \ l$	Multi-pattern matches
$tannot^?$	$::=$		Optional type annotations
		$: typ$	
$funcl\_aux$	$::=$	$x^l \ pat_1 ... pat_n \ tannot^? = exp$	Function clauses
$letbind\_aux$	$::=$	$pat \ tannot^? = exp$	Let bindings
		$funcl\_aux$	Value bindings
			Function bindings
$letbind$	$::=$	$letbind\_aux \ l$	Location-annotated let bindings
$funcl$	$::=$	$funcl\_aux \ l$	Location-annotated function clauses
$name\_t$	$::=$	$x^l$	Name or name with type for inductive types
		$(x^l : typ)$	

<i>name_ts</i>	$::=$ $  \quad name\_t_0 .. name\_t_n$	Names with optional type
<i>rule_aux</i>	$::=$ $  \quad x^l : \mathbf{forall} \ name\_t_1 .. name\_t_i. exp \Longrightarrow x_1^l \ exp_1 .. exp_n$	Inductively defined relation
<i>rule</i>	$::=$ $  \quad rule\_aux \ l$	Location-annotated inductive relation
<i>witness</i> <sup>?</sup>	$::=$ $ $ $  \quad \mathbf{witness \ type} \ x^l;$	Optional witness type name
<i>check</i> <sup>?</sup>	$::=$ $ $ $  \quad \mathbf{check} \ x^l;$	Option check name declaration
<i>functions</i> <sup>?</sup>	$::=$ $ $ $  \quad x^l : typ$ $  \quad x^l : typ; functions^?$	Optional names and types
<i>indreln_name_aux</i>	$::=$ $  \quad [x^l : typschm \ witness^? \ check^? \ functions^?]$	Name for inductively defined relation
<i>indreln_name</i>	$::=$ $  \quad indreln\_name\_aux \ l$	Location-annotated name
<i>typs</i>	$::=$ $  \quad typ_1 * \dots * typ_n$	Type lists
<i>ctor_def</i>	$::=$ $  \quad x^l \ \mathbf{of} \ typs$ $  \quad x^l$	Datatype definition clause
<i>texp</i>	$::=$ $  \quad typ$ $  \quad \langle   x_1^l : typ_1; \dots; x_n^l : typ_n; ^?   \rangle$ $  \quad   ^? \ ctor\_def_1   \dots   \ ctor\_def_n$	Type definition bodies Type abbreviations Record types Variant types
<i>name</i> <sup>?</sup>	$::=$ $ $ $  \quad [name = regexp]$	Optional name specification
<i>td</i>	$::=$ $  \quad x^l \ tnvars^l \ name^? = texp$ $  \quad x^l \ tnvars^l \ name^?$	Type definitions Definitions of opaque types

$c$	$::=$ $  \quad id\ tnvar^l$	Typeclass constraints
$cs$	$::=$ $ $ $  \quad c_1, \dots, c_i \Rightarrow$ $  \quad Nexp\_constraint_1, \dots, Nexp\_constraint_i \Rightarrow$ $  \quad c_1, \dots, c_i; Nexp\_constraint_1, \dots, Nexp\_constraint_n \Rightarrow$	Typeclass and length constraint  Must have > 0 constraints Must have > 0 constraints Must have > 0 of both form o
$c\_pre$	$::=$ $ $ $  \quad \mathbf{forall}\ tnvar_1^l \dots tnvar_n^l.cs$	Type and instance scheme prefix  Must have > 0 type variables
$typschm$	$::=$ $  \quad c\_pre\ typ$	Type schemes
$instschm$	$::=$ $  \quad c\_pre(id\ typ)$	Instance schemes
$target$	$::=$ $  \quad \mathbf{hol}$ $  \quad \mathbf{isabelle}$ $  \quad \mathbf{ocaml}$ $  \quad \mathbf{coq}$ $  \quad \mathbf{tex}$ $  \quad \mathbf{html}$ $  \quad \mathbf{lem}$	Backend target names
$open\_import$	$::=$ $  \quad \mathbf{open}$ $  \quad \mathbf{import}$ $  \quad \mathbf{open\ import}$ $  \quad \mathbf{include}$ $  \quad \mathbf{include\ import}$	Open or import statements
$\tau$	$::=$ $  \quad \{target_1; \dots; target_n\}$ $  \quad \{target_1; \dots; target_n\}$	Backend target name lists  all targets except the listed on
$\tau^?$	$::=$ $ $ $  \quad \tau$	Optional targets
$lemma\_typ$	$::=$ $  \quad \mathbf{assert}$ $  \quad \mathbf{lemma}$ $  \quad \mathbf{theorem}$	Types of Lemmata

<i>lemma_decl</i>	$::=$ $  \quad lemma\_typ \tau^? x^l : exp$	Lemmata and Tests
<i>dexp</i>	$::=$ $  \quad name\_s = string \ l$ $  \quad \mathbf{format} = string \ l$ $  \quad \mathbf{arguments} = exp_1 \dots exp_n \ l$ $  \quad \mathbf{targuments} = texp_1 \dots texp_n \ l$	declaration field-expressions
<i>declare_arg</i>	$::=$ $  \quad string$ $  \quad \langle   dexp_1; \dots; dexp_n; ? \ l   \rangle$	arguments to a declaration
<i>component</i>	$::=$ $  \quad \mathbf{module}$ $  \quad \mathbf{function}$ $  \quad \mathbf{type}$ $  \quad \mathbf{field}$	components
<i>termination_setting</i>	$::=$ $  \quad \mathbf{automatic}$ $  \quad \mathbf{manual}$	termination settings
<i>exhaustivity_setting</i>	$::=$ $  \quad \mathbf{exhaustive}$ $  \quad \mathbf{inexhaustive}$	exhaustivity settings
<i>elim_opt</i>	$::=$ $ $ $  \quad id$	optional terms used as eliminators for patten
<i>fixity_decl</i>	$::=$ $  \quad right\_assocnat$ $  \quad left\_assocnat$ $  \quad non\_assocnat$ $ $	fixity declarations for infix identifiers
<i>target_rep_rhs</i>	$::=$ $  \quad \mathbf{infix} \ fixity\_decl \ backtick\_string$ $  \quad exp$ $  \quad typ$ $  \quad \mathbf{special} \ string \ exp_1 \dots exp_n$ $ $	right hand side of a target representation dec
<i>target_rep_lhs</i>	$::=$ $  \quad target\_repcomponent \ id \ x_1^l \dots x_n^l$ $  \quad target\_repcomponent \ id \ tnvars^l$	left hand side of a target representation dec



<i>declare_def</i>	<pre> ::=   <b>declare</b> <math>\tau^?</math> <i>compile_messageid</i> = <i>string</i>   <b>declare</b> <math>\tau^?</math> <b>rename module</b> = <math>x^l</math>   <b>declare</b> <math>\tau^?</math> <b>rename component</b> <i>id</i> = <math>x^l</math>   <b>declare</b> <math>\tau^?</math> <i>ascii_repcomponent id</i> = <i>backtick_string</i>   <b>declare</b> <i>targettarget_rep</i> <i>target_rep_lhs</i> = <i>target_rep_rhs</i>   <b>declare</b> <i>set_flag</i> <math>x_1^l = x_2^l</math>   <b>declare</b> <math>\tau^?</math> <i>termination_argumentid</i> = <i>termination_setting</i>   <b>declare</b> <math>\tau^?</math> <i>pattern_matchexhaustivity_setting id tnvars</i><sup><i>l</i></sup> = [<i>id</i><sub>1</sub>; ...; <i>id</i><sub><i>n</i></sub>; ?] <i>elim_opt</i> </pre>
<i>val_def</i>	<pre> ::=   <b>let</b> <math>\tau^?</math> <i>letbind</i>   <b>let rec</b> <math>\tau^?</math> <i>funcl</i><sub>1</sub> <b>and</b> ... <b>and</b> <i>funcl</i><sub><i>n</i></sub>   <b>let inline</b> <math>\tau^?</math> <i>letbind</i>   <b>let lem_transform</b> <math>\tau^?</math> <i>letbind</i> </pre>
<i>ascii_opt</i>	<pre> ::=     [<i>backtick_string</i>] </pre>
<i>instance_decl</i>	<pre> ::=   <b>instance</b>   <i>default_instance</i> </pre>
<i>class_decl</i>	<pre> ::=   <b>class</b>   <b>class inline</b> </pre>
<i>val_spec</i>	<pre> ::=   <b>val</b> <math>x^l</math> <i>ascii_opt</i> : <i>typschm</i> </pre>
<i>def_aux</i>	<pre> ::=   <b>type</b> <i>td</i><sub>1</sub> <b>and</b> ... <b>and</b> <i>td</i><sub><i>n</i></sub>   <i>val_def</i>   <i>lemma_decl</i>   <i>declare_def</i>   <b>module</b> <math>x^l</math> = <b>struct</b> <i>defs</i> <b>end</b>   <b>module</b> <math>x^l</math> = <i>id</i>   <i>open_import id</i><sub>1</sub> ... <i>id</i><sub><i>n</i></sub>   <i>open_import</i> <math>\tau^?</math> <i>backtick_string</i><sub>1</sub> ... <i>backtick_string</i><sub><i>n</i></sub>   <b>indreln</b> <math>\tau^?</math> <i>indreln_name</i><sub>1</sub> <b>and</b> ... <b>and</b> <i>indreln_name</i><sub><i>i</i></sub> <i>rule</i><sub>1</sub> <b>and</b> ... <b>and</b> <i>rule</i><sub><i>n</i></sub>   <i>val_spec</i>   <i>class_decl</i>(<math>x^l</math> <i>tnvar</i><sup><i>l</i></sup>) <b>val</b> <math>\tau_1^?</math> <math>x_1^l</math> <i>ascii_opt</i><sub>1</sub> : <i>typ</i><sub>1</sub> <i>l</i><sub>1</sub> ... <b>val</b> <math>\tau_n^?</math> <math>x_n^l</math> <i>ascii_opt</i><sub><i>n</i></sub> : <i>typ</i><sub><i>n</i></sub> <i>l</i><sub><i>n</i></sub> <b>end</b>   <i>instance_decl instschm val_def</i><sub>1</sub> <i>l</i><sub>1</sub> ... <i>val_def</i><sub><i>n</i></sub> <i>l</i><sub><i>n</i></sub> <b>end</b> </pre>
<i>def</i>	<pre> ::=   <i>def_aux l</i> </pre>

$;;^?$	$::=$     $;;$		Optional double-semi-colon
$defs$	$::=$   $def_1 ; ;_1^? \dots def_n ; ;_n^?$		Definition sequences
$p$	$::=$   $x_1 \dots x_n . x$   <b>__list</b>   <b>__bool</b>   <b>__num</b>   <b>__set</b>   <b>__string</b>   <b>__unit</b>   <b>__bit</b>   <b>__vector</b>		Unique paths
$\sigma$	$::=$   $\{tnv_1 \mapsto t_1 \dots tnv_n \mapsto t_n\}$		Type variable substitutions
$t, u$	$::=$   $\alpha$   $t_1 \rightarrow t_2$   $t_1 * \dots * t_n$   $p \ t\_args$   $ne$   $\sigma(t)$   $\sigma(tnv)$   <b>curry</b> $(t\_multi, t)$	M M M	Internal types Multiple substitutions Single variable substitution Curried, multiple argument functions
$ne$	$::=$   $N$   $nat$   $ne_1 * ne_2$   $ne_1 + ne_2$   $(-ne)$   <b>normalize</b> $(ne)$   $ne_1 + \dots + ne_n$   <b>bitlength</b> $(bin)$   <b>bitlength</b> $(hex)$   <b>length</b> $(pat_1 \dots pat_n)$   <b>length</b> $(exp_1 \dots exp_n)$	M M M M M M	internal numeric expressions
$t\_args$	$::=$   $t_1 \dots t_n$   $\sigma(t\_args)$	M	Lists of types Multiple substitutions

$t\_multi$	$::=$ $  \quad (t_1 * .. * t_n)$ $  \quad \sigma(t\_multi)$	<div>Lists of types</div> <div>M Multiple substitutions</div>
$nec$	$::=$ $  \quad ne \langle nec$ $  \quad ne = nec$ $  \quad ne \leq nec$ $  \quad ne$	Numeric expression constraints
$names$	$::=$ $  \quad \{x_1, .., x_n\}$	Sets of names
$\mathcal{C}$	$::=$ $  \quad (p_1 \ tnv_1) .. (p_n \ tnv_n)$	Typeclass constraint lists
$env\_tag$	$::=$ $  \quad \mathbf{method}$ $  \quad \mathbf{val}$ $  \quad \mathbf{let}$	<div>Tags for the (non-constructor) value descriptions</div> <div>Bound to a method</div> <div>Specified with val</div> <div>Defined with let or indreln</div>
$v\_desc$	$::=$ $  \quad \langle \mathbf{forall} \ tnv s. t\_multi \rightarrow p, (x \ \mathbf{of} \ names) \rangle$ $  \quad \langle \mathbf{forall} \ tnv s. \mathcal{C} \Rightarrow t, env\_tag \rangle$	<div>Value descriptions</div> <div>Constructors</div> <div>Values</div>
$f\_desc$	$::=$ $  \quad \langle \mathbf{forall} \ tnv s. p \rightarrow t, (x \ \mathbf{of} \ names) \rangle$	Fields
$xs$	$::=$ $  \quad x_1 .. x_n$	
$\Sigma^{\mathcal{C}}$	$::=$ $  \quad \{(p_1 \ t_1), .., (p_n \ t_n)\}$ $  \quad \Sigma^{\mathcal{C}}_1 \cup .. \cup \Sigma^{\mathcal{C}}_n$	<div>Typeclass constraints</div> <div>M</div>
$\Sigma^{\mathcal{N}}$	$::=$ $  \quad \{nec_1, .., nec_n\}$ $  \quad \Sigma^{\mathcal{N}}_1 \cup .. \cup \Sigma^{\mathcal{N}}_n$	<div>Nexp constraint lists</div> <div>M</div>
$E$	$::=$ $  \quad \langle E^M, E^P, E^F, E^X \rangle$ $  \quad E_1 \uplus E_2$ $  \quad \epsilon$	<div>Environments</div> <div>M</div> <div>M</div>
$E^X$	$::=$ $  \quad \{x_1 \mapsto v\_desc_1, .., x_n \mapsto v\_desc_n\}$ $  \quad E_1^X \uplus .. \uplus E_n^X$	<div>Value environments</div> <div>M</div>

$E^F$	$::=$ $\mid \{x_1 \mapsto f\_desc_1, \dots, x_n \mapsto f\_desc_n\}$ $\mid E_1^F \uplus \dots \uplus E_n^F$	Field environments M
$E^M$	$::=$ $\mid \{x_1 \mapsto E_1, \dots, x_n \mapsto E_n\}$	Module environments
$E^P$	$::=$ $\mid \{x_1 \mapsto p_1, \dots, x_n \mapsto p_n\}$ $\mid E_1^P \uplus \dots \uplus E_n^P$	Path environments M
$E^L$	$::=$ $\mid \{x_1 \mapsto t_1, \dots, x_n \mapsto t_n\}$ $\mid \{x_1^l \mapsto t_1, \dots, x_n^l \mapsto t_n\}$ $\mid E_1^L \uplus \dots \uplus E_n^L$	Lexical bindings M
$tc\_abbrev$	$::=$ $\mid .t$ $\mid$	Type abbreviations
$tc\_def$	$::=$ $\mid tnvs\ tc\_abbrev$	Type and class constructor definitions Type constructors
$\Delta$	$::=$ $\mid \{p_1 \mapsto tc\_def_1, \dots, p_n \mapsto tc\_def_n\}$ $\mid \Delta_1 \uplus \Delta_2$	Type constructor definitions M
$\delta$	$::=$ $\mid \{p_1 \mapsto xs_1, \dots, p_n \mapsto xs_n\}$ $\mid \delta_1 \uplus \delta_2$	Typeclass definitions M
$inst$	$::=$ $\mid \mathcal{C} \Rightarrow (p\ t)$	A typeclass instance, t must not contain nested type constructors
$I$	$::=$ $\mid \{inst_1, \dots, inst_n\}$ $\mid I_1 \cup I_2$	Global instances M
$D$	$::=$ $\mid \langle \Delta, \delta, I \rangle$ $\mid D_1 \uplus D_2$ $\mid \epsilon$	Global type definition store M M
$terminals$	$::=$ $\mid \geq$ $\mid \rightarrow$ $\mid \leftarrow$	$\geq$ $\rightarrow$ $\leftarrow$

	$\Rightarrow$	$\Rightarrow$
	$\langle  $	$<  $
	$  \rangle$	$  >$
	$\cap$	
	$\cup$	
	$\oplus$	
	$\notin$	
	$\subset$	
	$\neq$	
	$\emptyset$	
	$\langle$	
	$\rangle$	
	$\vdash$	
	$,$	
	$\mapsto$	
	$\triangleright$	
	$\rightsquigarrow$	
	$\Rightarrow$	
	$-$	
	$\epsilon$	
<i>formula</i>	$::=$	
	<i>judgement</i>	
	$formula_1 \dots formula_n$	
	$E^M(x) \triangleright E$	Module lookup
	$E^P(x) \triangleright p$	Path lookup
	$E^F(x) \triangleright f\_desc$	Field lookup
	$E^X(x) \triangleright v\_desc$	Value lookup
	$E^L(x) \triangleright t$	Lexical binding lookup
	$\Delta(p) \triangleright tc\_def$	Type constructor lookup
	$\delta(p) \triangleright xs$	Type constructor lookup
	$\mathbf{dom}(E_1^M) \cap \mathbf{dom}(E_2^M) = \emptyset$	
	$\mathbf{dom}(E_1^X) \cap \mathbf{dom}(E_2^X) = \emptyset$	
	$\mathbf{dom}(E_1^F) \cap \mathbf{dom}(E_2^F) = \emptyset$	
	$\mathbf{dom}(E_1^P) \cap \mathbf{dom}(E_2^P) = \emptyset$	
	$\mathbf{disjoint\ doms}(E_1^L, \dots, E_n^L)$	Pairwise disjoint domains
	$\mathbf{disjoint\ doms}(E_1^X, \dots, E_n^X)$	Pairwise disjoint domains
	$\mathbf{compatible\ overlap}(x_1 \mapsto t_1, \dots, x_n \mapsto t_n)$	$(x_i = x_j) \Rightarrow (t_i = t_j)$
	$\mathbf{duplicates}(tnvs) = \emptyset$	
	$\mathbf{duplicates}(x_1, \dots, x_n) = \emptyset$	
	$x \notin \mathbf{dom}(E^L)$	
	$x \notin \mathbf{dom}(E^X)$	
	$x \notin \mathbf{dom}(E^F)$	
	$p \notin \mathbf{dom}(\delta)$	
	$p \notin \mathbf{dom}(\Delta)$	
	$\mathbf{FV}(t) \subset tnvs$	Free type variables

		$\mathbf{FV}(t\_multi) \subset tnvs$	Free type variables
		$\mathbf{FV}(\mathcal{C}) \subset tnvs$	Free type variables
		$inst \mathbf{IN} I$	
		$(p\ t) \notin I$	
		$E_1^L = E_2^L$	
		$E_1^X = E_2^X$	
		$E_1^F = E_2^F$	
		$E_1 = E_2$	
		$\Delta_1 = \Delta_2$	
		$\delta_1 = \delta_2$	
		$I_1 = I_2$	
		$names_1 = names_2$	
		$t_1 = t_2$	
		$\sigma_1 = \sigma_2$	
		$p_1 = p_2$	
		$xs_1 = xs_2$	
		$tnvs_1 = tnvs_2$	
$convert\_tnvars$	::=		
		$tnvars^l \rightsquigarrow tnvs$	
		$tnvar^l \rightsquigarrow tn timer$	
$look\_m$	::=		
		$E_1(x_1^l \dots x_n^l) \triangleright E_2$	Name path lookup
$look\_m\_id$	::=		
		$E_1(id) \triangleright E_2$	Module identifier lookup
$look\_tc$	::=		
		$E(id) \triangleright p$	Path identifier lookup
$check\_t$	::=		
		$\Delta \vdash t \mathbf{ok}$	Well-formed types
		$\Delta, tn timer \vdash t \mathbf{ok}$	Well-formed type/Nexps matching the application type
$teq$	::=		
		$\Delta \vdash t_1 = t_2$	Type equality
$convert\_typ$	::=		
		$\Delta, E \vdash typ \rightsquigarrow t$	Convert source types to internal types
		$\vdash Nexp \rightsquigarrow ne$	Convert and normalize numeric expressions
$convert\_typs$	::=		
		$\Delta, E \vdash typs \rightsquigarrow t\_multi$	
$check\_lit$	::=		
		$\vdash lit : t$	Typing literal constants

$inst\_field$	$::=$   $\Delta, E \vdash \mathbf{field} \ id : p \ t\_args \rightarrow t \triangleright (x \ \mathbf{of} \ names)$	Field typing (also returns c
$inst\_ctor$	$::=$   $\Delta, E \vdash \mathbf{ctor} \ id : t\_multi \rightarrow p \ t\_args \triangleright (x \ \mathbf{of} \ names)$	Data constructor typing (a
$inst\_val$	$::=$   $\Delta, E \vdash \mathbf{val} \ id : t \triangleright \Sigma^C$	Typing top-level bindings,
$not\_ctor$	$::=$   $E, E^L \vdash x \ \mathbf{not} \ \mathbf{ctor}$	$v$ is not bound to a data co
$not\_shadowed$	$::=$   $E^L \vdash id \ \mathbf{not} \ \mathbf{shadowed}$	$id$ is not lexically shadowed
$check\_pat$	$::=$   $\Delta, E, E_1^L \vdash pat : t \triangleright E_2^L$   $\Delta, E, E_1^L \vdash pat\_aux : t \triangleright E_2^L$	Typing patterns, building t Typing patterns, building t
$id\_field$	$::=$   $E \vdash id \ \mathbf{field}$	Check that the identifier is
$id\_value$	$::=$   $E \vdash id \ \mathbf{value}$	Check that the identifier is
$check\_exp$	$::=$   $\Delta, E, E^L \vdash exp : t \triangleright \Sigma^C, \Sigma^N$   $\Delta, E, E^L \vdash exp\_aux : t \triangleright \Sigma^C, \Sigma^N$   $\Delta, E, E_1^L \vdash qbind_1 .. qbind_n \triangleright E_2^L, \Sigma^C$   $\Delta, E, E_1^L \vdash \mathbf{list} \ qbind_1 .. qbind_n \triangleright E_2^L, \Sigma^C$   $\Delta, E, E^L \vdash funcl \triangleright \{x \mapsto t\}, \Sigma^C, \Sigma^N$   $\Delta, E, E_1^L \vdash letbind \triangleright E_2^L, \Sigma^C, \Sigma^N$	Typing expressions, collect Typing expressions, collect Build the environment for c Build the environment for c Build the environment for c Build the environment for c
$check\_rule$	$::=$   $\Delta, E, E^L \vdash rule \triangleright \{x \mapsto t\}, \Sigma^C, \Sigma^N$	Build the environment for c
$check\_texp\_tc$	$::=$   $xs, \Delta_1, E \vdash \mathbf{tc} \ td \triangleright \Delta_2, E^P$	Extract the type constructo
$check\_texps\_tc$	$::=$   $xs, \Delta_1, E \vdash \mathbf{tc} \ td_1 .. td_i \triangleright \Delta_2, E^P$	Extract the type constructo
$check\_texp$	$::=$   $\Delta, E \vdash tnvs \ p = texp \triangleright \langle E^F, E^X \rangle$	Check a type definition, wi
$check\_texps$	$::=$   $xs, \Delta, E \vdash td_1 .. td_n \triangleright \langle E^F, E^X \rangle$	

<i>convert_class</i>	$::=$ $\mid \delta, E \vdash id \rightsquigarrow p$	Lookup a type class
<i>solve_class_constraint</i>	$::=$ $\mid I \vdash (p \ t) \textbf{IN } \mathcal{C}$	Solve class constraint
<i>solve_class_constraints</i>	$::=$ $\mid I \vdash \Sigma^{\mathcal{C}} \triangleright \mathcal{C}$	Solve class constraints
<i>check_val_def</i>	$::=$ $\mid \Delta, I, E \vdash val\_def \triangleright E^x$	Check a value definition
<i>check_t_instance</i>	$::=$ $\mid \Delta, (\alpha_1, \dots, \alpha_n) \vdash t \textbf{instance}$	Check that $t$ be a typeclass instance
<i>check_defs</i>	$::=$ $\mid \overline{z_j}^j, D_1, E_1 \vdash def \triangleright D_2, E_2$ $\mid \overline{z_j}^j, D_1, E_1 \vdash defs \triangleright D_2, E_2$	Check a definition Check definitions, given module path, definitions
<i>judgement</i>	$::=$ $\mid$ <i>convert_tnvars</i> $\mid$ <i>look_m</i> $\mid$ <i>look_m_id</i> $\mid$ <i>look_tc</i> $\mid$ <i>check_t</i> $\mid$ <i>teq</i> $\mid$ <i>convert_typ</i> $\mid$ <i>convert_typs</i> $\mid$ <i>check_lit</i> $\mid$ <i>inst_field</i> $\mid$ <i>inst_ctor</i> $\mid$ <i>inst_val</i> $\mid$ <i>not_ctor</i> $\mid$ <i>not_shadowed</i> $\mid$ <i>check_pat</i> $\mid$ <i>id_field</i> $\mid$ <i>id_value</i> $\mid$ <i>check_exp</i> $\mid$ <i>check_rule</i> $\mid$ <i>check_texp_tc</i> $\mid$ <i>check_texprs_tc</i> $\mid$ <i>check_texp</i> $\mid$ <i>check_texprs</i> $\mid$ <i>convert_class</i> $\mid$ <i>solve_class_constraint</i> $\mid$ <i>solve_class_constraints</i> $\mid$ <i>check_val_def</i>	



		<i>check_t_instance</i>
		<i>check_defs</i>
<i>user_syntax</i>	::=	
		<i>n</i>
		<i>num</i>
		<i>nat</i>
		<i>hex</i>
		<i>bin</i>
		<i>string</i>
		<i>backtick_string</i>
		<i>regexp</i>
		<i>x</i>
		<i>ix</i>
		<i>l</i>
		<i>x<sup>l</sup></i>
		<i>ix<sup>l</sup></i>
		$\alpha$
		$\alpha^l$
		<i>N</i>
		<i>N<sup>l</sup></i>
		<i>id</i>
		<i>tnv</i>
		<i>tnvar<sup>l</sup></i>
		<i>tnvs</i>
		<i>tnvars<sup>l</sup></i>
		<i>Nexp_aux</i>
		<i>Nexp</i>
		<i>Nexp_constraint_aux</i>
		<i>Nexp_constraint</i>
		<i>typ_aux</i>
		<i>typ</i>
		<i>lit_aux</i>
		<i>lit</i>
		<i>;</i> <sup>?</sup>
		<i>pat_aux</i>
		<i>pat</i>
		<i>fpat</i>
		<i> </i> <sup>?</sup>
		<i>exp_aux</i>
		<i>exp</i>
		<i>q</i>
		<i>qbind</i>
		<i>fexp</i>
		<i>fexps</i>
		<i>pexp</i>

*psexp*  
*tannot?*  
*funcl\_aux*  
*letbind\_aux*  
*letbind*  
*funcl*  
*name\_t*  
*name\_ts*  
*rule\_aux*  
*rule*  
*witness?*  
*check?*  
*functions?*  
*indreln\_name\_aux*  
*indreln\_name*  
*typs*  
*ctor\_def*  
*texp*  
*name?*  
*td*  
*c*  
*cs*  
*c\_pre*  
*typschm*  
*instschm*  
*target*  
*open\_import*  
 $\tau$   
 $\tau?$   
*lemma\_typ*  
*lemma\_decl*  
*dexp*  
*declare\_arg*  
*component*  
*termination\_setting*  
*exhaustivity\_setting*  
*elim\_opt*  
*fixity\_decl*  
*target\_rep\_rhs*  
*target\_rep\_lhs*  
*declare\_def*  
*val\_def*  
*ascii\_opt*  
*instance\_decl*  
*class\_decl*  
*val\_spec*

$def\_aux$   
 $def$   
 $;;^?$   
 $defs$   
 $p$   
 $\sigma$   
 $t$   
 $ne$   
 $t\_args$   
 $t\_multi$   
 $nec$   
 $names$   
 $\mathcal{C}$   
 $env\_tag$   
 $v\_desc$   
 $f\_desc$   
 $xs$   
 $\Sigma^{\mathcal{C}}$   
 $\Sigma^{\mathcal{N}}$   
 $E$   
 $E^{\mathbf{x}}$   
 $E^{\mathbf{F}}$   
 $E^{\mathbf{M}}$   
 $E^{\mathbf{P}}$   
 $E^{\mathbf{L}}$   
 $tc\_abbrev$   
 $tc\_def$   
 $\Delta$   
 $\delta$   
 $inst$   
 $I$   
 $D$   
 $terminals$   
 $formula$

$$\boxed{tnvars^l \rightsquigarrow tnvs}$$

$$\frac{tnvar_1^l \rightsquigarrow tn v_1 \quad \dots \quad tnvar_n^l \rightsquigarrow tn v_n}{tnvar_1^l \dots tnvar_n^l \rightsquigarrow tn v_1 \dots tn v_n} \quad \text{CONVERT\_TNVARS\_NONE}$$

$$\boxed{tnvar^l \rightsquigarrow tn v}$$

$$\frac{}{\alpha \, l \rightsquigarrow \alpha} \quad \text{CONVERT\_TNVAR\_A}$$

$$\frac{}{N \, l \rightsquigarrow N} \quad \text{CONVERT\_TNVAR\_N}$$

$$\boxed{E_1(x_1^l \dots x_n^l) \triangleright E_2}$$

Name path lookup

$$\frac{}{E() \triangleright E} \quad \text{LOOK\_M\_NONE}$$

$$\frac{\begin{array}{c} E^M(x) \triangleright E_1 \\ E_1(\overline{y_i^l}^i) \triangleright E_2 \end{array}}{\langle E^M, E^P, E^F, E^X \rangle(x \ l \ \overline{y_i^l}^i) \triangleright E_2} \quad \text{LOOK\_M\_SOME}$$

$E_1(id) \triangleright E_2$       Module identifier lookup

$$\frac{E_1(\overline{y_i^l}^i \ x \ l_1) \triangleright E_2}{E_1(\overline{y_i^l}^i \ x \ l_1 \ l_2) \triangleright E_2} \quad \text{LOOK\_M\_ID\_ALL}$$

$E(id) \triangleright p$       Path identifier lookup

$$\frac{\begin{array}{c} E(\overline{y_i^l}^i) \triangleright \langle E^M, E^P, E^F, E^X \rangle \\ E^P(x) \triangleright p \end{array}}{E(\overline{y_i^l}^i \ x \ l_1 \ l_2) \triangleright p} \quad \text{LOOK\_TC\_ALL}$$

$\Delta \vdash t \text{ ok}$       Well-formed types

$$\overline{\Delta \vdash \alpha \text{ ok}} \quad \text{CHECK\_T\_VAR}$$

$$\frac{\begin{array}{c} \Delta \vdash t_1 \text{ ok} \\ \Delta \vdash t_2 \text{ ok} \end{array}}{\Delta \vdash t_1 \rightarrow t_2 \text{ ok}} \quad \text{CHECK\_T\_FN}$$

$$\frac{\Delta \vdash t_1 \text{ ok} \quad \dots \quad \Delta \vdash t_n \text{ ok}}{\Delta \vdash t_1 * \dots * t_n \text{ ok}} \quad \text{CHECK\_T\_TUP}$$

$$\frac{\begin{array}{c} \Delta(p) \triangleright tnv_1 .. tnv_n \text{ tc\_abbrev} \\ \Delta, tnv_1 \vdash t_1 \text{ ok} \quad \dots \quad \Delta, tnv_n \vdash t_n \text{ ok} \end{array}}{\Delta \vdash p \ t_1 .. t_n \text{ ok}} \quad \text{CHECK\_T\_APP}$$

$\Delta, tnv \vdash t \text{ ok}$       Well-formed type/Nexps matching the application type variable

$$\frac{\Delta \vdash t \text{ ok}}{\Delta, \alpha \vdash t \text{ ok}} \quad \text{CHECK\_TLEN\_T}$$

$$\overline{\Delta, N \vdash ne \text{ ok}} \quad \text{CHECK\_TLEN\_LEN}$$

$\Delta \vdash t_1 = t_2$       Type equality

$$\frac{\Delta \vdash t \text{ ok}}{\Delta \vdash t = t} \quad \text{TEQ\_REFL}$$

$$\frac{\Delta \vdash t_2 = t_1}{\Delta \vdash t_1 = t_2} \quad \text{TEQ\_SYM}$$

$$\frac{\begin{array}{c} \Delta \vdash t_1 = t_2 \\ \Delta \vdash t_2 = t_3 \end{array}}{\Delta \vdash t_1 = t_3} \quad \text{TEQ\_TRANS}$$

$$\frac{\begin{array}{c} \Delta \vdash t_1 = t_3 \\ \Delta \vdash t_2 = t_4 \end{array}}{\Delta \vdash t_1 \rightarrow t_2 = t_3 \rightarrow t_4} \quad \text{TEQ\_ARROW}$$

$$\frac{\Delta \vdash t_1 = u_1 \quad \dots \quad \Delta \vdash t_n = u_n}{\Delta \vdash t_1 * \dots * t_n = u_1 * \dots * u_n} \quad \text{TEQ\_TUP}$$

$$\frac{\Delta(p) \triangleright \alpha_1 .. \alpha_n \quad \Delta \vdash t_1 = u_1 \quad .. \quad \Delta \vdash t_n = u_n}{\Delta \vdash p \ t_1 .. t_n = p \ u_1 .. u_n} \quad \text{TEQ\_APP}$$

$$\frac{\Delta(p) \triangleright \alpha_1 .. \alpha_n . u}{\Delta \vdash p \ t_1 .. t_n = \{\alpha_1 \mapsto t_1 .. \alpha_n \mapsto t_n\}(u)} \quad \text{TEQ\_EXPAND}$$

$$\frac{ne = \mathbf{normalize}(ne')}{\Delta \vdash ne = ne'} \quad \text{TEQ\_NEXP}$$

$\boxed{\Delta, E \vdash typ \rightsquigarrow t}$  Convert source types to internal types

$$\overline{\Delta, E \vdash \alpha \ l' \ l \rightsquigarrow \alpha} \quad \text{CONVERT\_TYP\_VAR}$$

$$\frac{\Delta, E \vdash typ_1 \rightsquigarrow t_1 \quad \Delta, E \vdash typ_2 \rightsquigarrow t_2}{\Delta, E \vdash typ_1 \rightarrow typ_2 \ l \rightsquigarrow t_1 \rightarrow t_2} \quad \text{CONVERT\_TYP\_FN}$$

$$\frac{\Delta, E \vdash typ_1 \rightsquigarrow t_1 \quad .... \quad \Delta, E \vdash typ_n \rightsquigarrow t_n}{\Delta, E \vdash typ_1 * .... * typ_n \ l \rightsquigarrow t_1 * .... * t_n} \quad \text{CONVERT\_TYP\_TUP}$$

$$\frac{\Delta, E \vdash typ_1 \rightsquigarrow t_1 \quad .. \quad \Delta, E \vdash typ_n \rightsquigarrow t_n \quad E(id) \triangleright p \quad \Delta(p) \triangleright \alpha_1 .. \alpha_n \ tc\_abbrev}{\Delta, E \vdash id \ typ_1 .. typ_n \ l \rightsquigarrow p \ t_1 .. t_n} \quad \text{CONVERT\_TYP\_APP}$$

$$\frac{\vdash Nexp \rightsquigarrow ne}{\Delta, E \vdash Nexp \rightsquigarrow ne} \quad \text{CONVERT\_TYP\_NEXP}$$

$$\frac{\Delta, E \vdash typ \rightsquigarrow t}{\Delta, E \vdash (typ) \ l \rightsquigarrow t} \quad \text{CONVERT\_TYP\_PAREN}$$

$$\frac{\Delta, E \vdash typ \rightsquigarrow t_1 \quad \Delta \vdash t_1 = t_2}{\Delta, E \vdash typ \rightsquigarrow t_2} \quad \text{CONVERT\_TYP\_EQ}$$

$\boxed{\vdash Nexp \rightsquigarrow ne}$  Convert and normalize numeric expressions

$$\overline{\vdash N \ l \rightsquigarrow N} \quad \text{CONVERT\_NEXP\_VAR}$$

$$\overline{\vdash num \ l \rightsquigarrow nat} \quad \text{CONVERT\_NEXP\_NUM}$$

$$\frac{\vdash Nexp_1 \rightsquigarrow ne_1 \quad \vdash Nexp_2 \rightsquigarrow ne_2}{\vdash Nexp_1 * Nexp_2 \ l \rightsquigarrow ne_1 * ne_2} \quad \text{CONVERT\_NEXP\_MULT}$$

$$\frac{\vdash Nexp_1 \rightsquigarrow ne_1 \quad \vdash Nexp_2 \rightsquigarrow ne_2}{\vdash Nexp_1 + Nexp_2 \ l \rightsquigarrow ne_1 + ne_2} \quad \text{CONVERT\_NEXP\_ADD}$$

$\boxed{\Delta, E \vdash typs \rightsquigarrow t\_multi}$

$$\frac{\Delta, E \vdash typ_1 \rightsquigarrow t_1 \quad .. \quad \Delta, E \vdash typ_n \rightsquigarrow t_n}{\Delta, E \vdash typ_1 * .. * typ_n \rightsquigarrow (t_1 * .. * t_n)} \quad \text{CONVERT\_TYP\_ALL}$$

$\boxed{\vdash lit : t}$  Typing literal constants

$\overline{\vdash \mathbf{true} \, l : \mathbf{\_bool}}$	CHECK_LIT_TRUE
$\overline{\vdash \mathbf{false} \, l : \mathbf{\_bool}}$	CHECK_LIT_FALSE
$\overline{\vdash \mathbf{num} \, l : \mathbf{\_num}}$	CHECK_LIT_NUM
$\frac{\mathit{nat} = \mathbf{bitlength}(\mathit{hex})}{\vdash \mathit{hex} \, l : \mathbf{\_vector} \, \mathit{nat} \, \mathbf{\_bit}}$	CHECK_LIT_HEX
$\frac{\mathit{nat} = \mathbf{bitlength}(\mathit{bin})}{\vdash \mathit{bin} \, l : \mathbf{\_vector} \, \mathit{nat} \, \mathbf{\_bit}}$	CHECK_LIT_BIN
$\overline{\vdash \mathit{string} \, l : \mathbf{\_string}}$	CHECK_LIT_STRING
$\overline{\vdash () \, l : \mathbf{\_unit}}$	CHECK_LIT_UNIT
$\overline{\vdash \mathbf{bitzero} \, l : \mathbf{\_bit}}$	CHECK_LIT_BITZERO
$\overline{\vdash \mathbf{bitone} \, l : \mathbf{\_bit}}$	CHECK_LIT_BITONE
$\Delta, E \vdash \mathbf{field} \, \mathit{id} : p \, t\_args \rightarrow t \triangleright (x \mathbf{of} \, \mathit{names})$	Field typing (also returns canonical field names)
$ \begin{array}{l} E(\overline{x_i^l}^i) \triangleright \langle E^M, E^P, E^F, E^X \rangle \\ E^F(y) \triangleright \langle \mathbf{forall} \, \mathit{tnv}_1 .. \mathit{tnv}_n.p \rightarrow t, (z \mathbf{of} \, \mathit{names}) \rangle \\ \Delta \vdash t_1 \mathbf{ok} \quad .. \quad \Delta \vdash t_n \mathbf{ok} \end{array} $	
$\Delta, E \vdash \mathbf{field} \, \overline{x_i^l}^i \, y \, l_1 \, l_2 : p \, t_1 .. t_n \rightarrow \{\mathit{tnv}_1 \mapsto t_1 .. \mathit{tnv}_n \mapsto t_n\}(t) \triangleright (z \mathbf{of} \, \mathit{names})$	INST_FIELD_ALL
$\Delta, E \vdash \mathbf{ctor} \, \mathit{id} : t\_multi \rightarrow p \, t\_args \triangleright (x \mathbf{of} \, \mathit{names})$	Data constructor typing (also returns canonical constructors)
$ \begin{array}{l} E(\overline{x_i^l}^i) \triangleright \langle E^M, E^P, E^F, E^X \rangle \\ E^X(y) \triangleright \langle \mathbf{forall} \, \mathit{tnv}_1 .. \mathit{tnv}_n.t\_multi \rightarrow p, (z \mathbf{of} \, \mathit{names}) \rangle \\ \Delta \vdash t_1 \mathbf{ok} \quad .. \quad \Delta \vdash t_n \mathbf{ok} \end{array} $	
$\Delta, E \vdash \mathbf{ctor} \, \overline{x_i^l}^i \, y \, l_1 \, l_2 : \{\mathit{tnv}_1 \mapsto t_1 .. \mathit{tnv}_n \mapsto t_n\}(t\_multi) \rightarrow p \, t_1 .. t_n \triangleright (z \mathbf{of} \, \mathit{names})$	INST_CTOR_ALL
$\Delta, E \vdash \mathbf{val} \, \mathit{id} : t \triangleright \Sigma^C$	Typing top-level bindings, collecting typeclass constraints
$ \begin{array}{l} E(\overline{x_i^l}^i) \triangleright \langle E^M, E^P, E^F, E^X \rangle \\ E^X(y) \triangleright \langle \mathbf{forall} \, \mathit{tnv}_1 .. \mathit{tnv}_n.(p_1 \, \mathit{tnv}'_1) .. (p_i \, \mathit{tnv}'_i) \Rightarrow t, \mathit{env\_tag} \rangle \\ \Delta \vdash t_1 \mathbf{ok} \quad .. \quad \Delta \vdash t_n \mathbf{ok} \\ \sigma = \{\mathit{tnv}_1 \mapsto t_1 .. \mathit{tnv}_n \mapsto t_n\} \end{array} $	
$\Delta, E \vdash \mathbf{val} \, \overline{x_i^l}^i \, y \, l_1 \, l_2 : \sigma(t) \triangleright \{(p_1 \, \sigma(\mathit{tnv}'_1)), .., (p_i \, \sigma(\mathit{tnv}'_i))\}$	INST_VAL_ALL
$E, E^L \vdash x \mathbf{not} \, \mathbf{ctor}$	$v$ is not bound to a data constructor
$\frac{E^L(x) \triangleright t}{E, E^L \vdash x \mathbf{not} \, \mathbf{ctor}}$	NOT_CTOR_VAL
$\frac{x \notin \mathbf{dom}(E^X)}{\langle E^M, E^P, E^F, E^X \rangle, E^L \vdash x \mathbf{not} \, \mathbf{ctor}}$	NOT_CTOR_UNBOUND
$\frac{E^X(x) \triangleright \langle \mathbf{forall} \, \mathit{tnv}_1 .. \mathit{tnv}_n.(p_1 \, \mathit{tnv}'_1) .. (p_i \, \mathit{tnv}'_i) \Rightarrow t, \mathit{env\_tag} \rangle}{\langle E^M, E^P, E^F, E^X \rangle, E^L \vdash x \mathbf{not} \, \mathbf{ctor}}$	NOT_CTOR_BOUND

$E^L \vdash id$  **not shadowed**      $id$  is not lexically shadowed

$$\frac{x \notin \mathbf{dom}(E^L)}{E^L \vdash x \ l_1 \ l_2 \mathbf{not shadowed}} \quad \text{NOT\_SHADOWED\_SING}$$

$$\frac{}{E^L \vdash x_1^l \dots x_n^l . y^l . z^l \ l \mathbf{not shadowed}} \quad \text{NOT\_SHADOWED\_MULTI}$$

$\Delta, E, E_1^L \vdash pat : t \triangleright E_2^L$      Typing patterns, building their binding environment

$$\frac{\Delta, E, E_1^L \vdash pat\_aux : t \triangleright E_2^L}{\Delta, E, E_1^L \vdash pat\_aux \ l : t \triangleright E_2^L} \quad \text{CHECK\_PAT\_ALL}$$

$\Delta, E, E_1^L \vdash pat\_aux : t \triangleright E_2^L$      Typing patterns, building their binding environment

$$\frac{\Delta \vdash t \mathbf{ok}}{\Delta, E, E^L \vdash \_ : t \triangleright \{ \}} \quad \text{CHECK\_PAT\_AUX\_WILD}$$

$$\frac{\Delta, E, E_1^L \vdash pat : t \triangleright E_2^L \quad x \notin \mathbf{dom}(E_2^L)}{\Delta, E, E_1^L \vdash (pat \mathbf{as} \ x \ l) : t \triangleright E_2^L \uplus \{x \mapsto t\}} \quad \text{CHECK\_PAT\_AUX\_AS}$$

$$\frac{\Delta, E, E_1^L \vdash pat : t \triangleright E_2^L \quad \Delta, E \vdash typ \rightsquigarrow t}{\Delta, E, E_1^L \vdash (pat : typ) : t \triangleright E_2^L} \quad \text{CHECK\_PAT\_AUX\_TYP}$$

$\Delta, E \vdash \mathbf{ctor} \ id : (t_1 * \dots * t_n) \rightarrow p \ t\_args \triangleright (x \mathbf{of} \ names)$

$E^L \vdash id$  **not shadowed**

$\Delta, E, E^L \vdash pat_1 : t_1 \triangleright E_1^L \quad \dots \quad \Delta, E, E^L \vdash pat_n : t_n \triangleright E_n^L$

**disjoint doms**  $(E_1^L, \dots, E_n^L)$

$$\frac{}{\Delta, E, E^L \vdash id \ pat_1 \dots pat_n : p \ t\_args \triangleright E_1^L \uplus \dots \uplus E_n^L} \quad \text{CHECK\_PAT\_AUX\_IDENT\_CONSTR}$$

$$\frac{\Delta \vdash t \mathbf{ok} \quad E, E^L \vdash x \mathbf{not ctor}}{\Delta, E, E^L \vdash x \ l_1 \ l_2 : t \triangleright \{x \mapsto t\}} \quad \text{CHECK\_PAT\_AUX\_VAR}$$

$$\frac{\Delta, E \vdash \mathbf{field} \ id_i : p \ t\_args \rightarrow t_i \triangleright (x_i \mathbf{of} \ names)^i \quad \Delta, E, E^L \vdash pat_i : t_i \triangleright E_i^L \quad \mathbf{disjoint doms}(\overline{E_i^L}^i) \quad \mathbf{duplicates}(\overline{x_i}^i) = \emptyset}{\Delta, E, E^L \vdash \langle | id_i = pat_i \ \overline{l_i}^i ; ? | \rangle : p \ t\_args \triangleright \uplus \overline{E_i^L}^i} \quad \text{CHECK\_PAT\_AUX\_RECORD}$$

$\Delta, E, E^L \vdash pat_1 : t \triangleright E_1^L \quad \dots \quad \Delta, E, E^L \vdash pat_n : t \triangleright E_n^L$

**disjoint doms**  $(E_1^L, \dots, E_n^L)$

**length**  $(pat_1 \dots pat_n) = nat$

$$\frac{}{\Delta, E, E^L \vdash [| pat_1 ; \dots ; pat_n ; ? |] : \_ \mathbf{vector} \ nat \ t \triangleright E_1^L \uplus \dots \uplus E_n^L} \quad \text{CHECK\_PAT\_AUX\_VECTOR}$$

$\Delta, E, E^L \vdash pat_1 : \_ \mathbf{vector} \ ne_1 \ t \triangleright E_1^L \quad \dots \quad \Delta, E, E^L \vdash pat_n : \_ \mathbf{vector} \ ne_n \ t \triangleright E_n^L$

**disjoint doms**  $(E_1^L, \dots, E_n^L)$

$ne' = ne_1 + \dots + ne_n$

$$\frac{}{\Delta, E, E^L \vdash [| pat_1 \dots pat_n |] : \_ \mathbf{vector} \ ne' \ t \triangleright E_1^L \uplus \dots \uplus E_n^L} \quad \text{CHECK\_PAT\_AUX\_VECTOR}$$

$\Delta, E, E^L \vdash pat_1 : t_1 \triangleright E_1^L \quad \dots \quad \Delta, E, E^L \vdash pat_n : t_n \triangleright E_n^L$

**disjoint doms**  $(E_1^L, \dots, E_n^L)$

$$\frac{}{\Delta, E, E^L \vdash (pat_1, \dots, pat_n) : t_1 * \dots * t_n \triangleright E_1^L \uplus \dots \uplus E_n^L} \quad \text{CHECK\_PAT\_AUX\_TUP}$$

$$\begin{array}{c}
\Delta \vdash t \text{ ok} \\
\Delta, E, E^L \vdash pat_1 : t \triangleright E_1^L \quad \dots \quad \Delta, E, E^L \vdash pat_n : t \triangleright E_n^L \\
\text{disjoint doms}(E_1^L, \dots, E_n^L) \\
\hline
\Delta, E, E^L \vdash [pat_1; \dots; pat_n; ?] : \text{list } t \triangleright E_1^L \uplus \dots \uplus E_n^L
\end{array}
\quad \text{CHECK\_PAT\_AUX\_LIST}$$

$$\begin{array}{c}
\Delta, E, E_1^L \vdash pat : t \triangleright E_2^L \\
\hline
\Delta, E, E_1^L \vdash (pat) : t \triangleright E_2^L
\end{array}
\quad \text{CHECK\_PAT\_AUX\_PAREN}$$

$$\begin{array}{c}
\Delta, E, E_1^L \vdash pat_1 : t \triangleright E_2^L \\
\Delta, E, E_1^L \vdash pat_2 : \text{list } t \triangleright E_3^L \\
\text{disjoint doms}(E_2^L, E_3^L) \\
\hline
\Delta, E, E_1^L \vdash pat_1 :: pat_2 : \text{list } t \triangleright E_2^L \uplus E_3^L
\end{array}
\quad \text{CHECK\_PAT\_AUX\_CONS}$$

$$\begin{array}{c}
\vdash lit : t \\
\hline
\Delta, E, E^L \vdash lit : t \triangleright \{ \}
\end{array}
\quad \text{CHECK\_PAT\_AUX\_LIT}$$

$$\begin{array}{c}
E, E^L \vdash x \text{ not ctor} \\
\hline
\Delta, E, E^L \vdash x l + num : \text{num} \triangleright \{ x \mapsto \text{num} \}
\end{array}
\quad \text{CHECK\_PAT\_AUX\_NUM\_ADD}$$

$E \vdash id \text{ field}$  Check that the identifier is a permissible field identifier

$$\begin{array}{c}
E^F(x) \triangleright f\_desc \\
\hline
\langle E^M, E^P, E^F, E^X \rangle \vdash x l_1 l_2 \text{ field}
\end{array}
\quad \text{ID\_FIELD\_EMPTY}$$

$$\begin{array}{c}
E^M(x) \triangleright E \\
x \notin \text{dom}(E^F) \\
E \vdash \overline{y_i^L}^i z^l l_2 \text{ field} \\
\hline
\langle E^M, E^P, E^F, E^X \rangle \vdash x l_1. \overline{y_i^L}^i z^l l_2 \text{ field}
\end{array}
\quad \text{ID\_FIELD\_CONS}$$

$E \vdash id \text{ value}$  Check that the identifier is a permissible value identifier

$$\begin{array}{c}
E^X(x) \triangleright v\_desc \\
\hline
\langle E^M, E^P, E^F, E^X \rangle \vdash x l_1 l_2 \text{ value}
\end{array}
\quad \text{ID\_VALUE\_EMPTY}$$

$$\begin{array}{c}
E^M(x) \triangleright E \\
x \notin \text{dom}(E^X) \\
E \vdash \overline{y_i^L}^i z^l l_2 \text{ value} \\
\hline
\langle E^M, E^P, E^F, E^X \rangle \vdash x l_1. \overline{y_i^L}^i z^l l_2 \text{ value}
\end{array}
\quad \text{ID\_VALUE\_CONS}$$

$\Delta, E, E^L \vdash exp : t \triangleright \Sigma^C, \Sigma^N$  Typing expressions, collecting typeclass and index constraints

$$\begin{array}{c}
\Delta, E, E^L \vdash exp\_aux : t \triangleright \Sigma^C, \Sigma^N \\
\hline
\Delta, E, E^L \vdash exp\_aux l : t \triangleright \Sigma^C, \Sigma^N
\end{array}
\quad \text{CHECK\_EXP\_ALL}$$

$\Delta, E, E^L \vdash exp\_aux : t \triangleright \Sigma^C, \Sigma^N$  Typing expressions, collecting typeclass and index constraints

$$\begin{array}{c}
E^L(x) \triangleright t \\
\hline
\Delta, E, E^L \vdash x l_1 l_2 : t \triangleright \{ \}, \{ \}
\end{array}
\quad \text{CHECK\_EXP\_AUX\_VAR}$$

$$\begin{array}{c}
\hline
\Delta, E, E^L \vdash N : \text{num} \triangleright \{ \}, \{ \}
\end{array}
\quad \text{CHECK\_EXP\_AUX\_NVAR}$$

$E^L \vdash id \text{ not shadowed}$

$E \vdash id \text{ value}$

$$\begin{array}{c}
\Delta, E \vdash \text{ctor } id : t\_multi \rightarrow p t\_args \triangleright (x \text{ of names}) \\
\hline
\Delta, E, E^L \vdash id : \text{curry}(t\_multi, p t\_args) \triangleright \{ \}, \{ \}
\end{array}
\quad \text{CHECK\_EXP\_AUX\_CTOR}$$



$$\begin{array}{c}
\frac{E^L \vdash id \text{ not shadowed} \quad E \vdash id \text{ value} \quad \Delta, E \vdash \mathbf{val} \, id : t \triangleright \Sigma^C}{\Delta, E, E^L \vdash id : t \triangleright \Sigma^C, \{ \}} \text{ CHECK\_EXP\_AUX\_VAL} \\
\\
\frac{\Delta, E, E^L \vdash pat_1 : t_1 \triangleright E_1^L \quad \dots \quad \Delta, E, E^L \vdash pat_n : t_n \triangleright E_n^L \quad \Delta, E, E^L \uplus E_1^L \uplus \dots \uplus E_n^L \vdash exp : u \triangleright \Sigma^C, \Sigma^N \quad \mathbf{disjoint \, doms} \, (E_1^L, \dots, E_n^L)}{\Delta, E, E^L \vdash \mathbf{fun} \, pat_1 \dots pat_n \rightarrow exp \, l : \mathbf{curry} \, ((t_1 * \dots * t_n), u) \triangleright \Sigma^C, \Sigma^N} \text{ CHECK\_EXP\_AUX\_FN} \\
\\
\frac{\frac{\Delta, E, E^L \vdash pat_i : t \triangleright E_i^L}{\Delta, E, E^L \uplus E_i^L \vdash exp_i : u \triangleright \Sigma_i^C, \Sigma_i^N}}{\Delta, E, E^L \vdash \mathbf{function} \, [? \, pat_i \rightarrow exp_i \, l_i^i \, \mathbf{end} : t \rightarrow u \triangleright \overline{\Sigma_i^C}^i, \overline{\Sigma_i^N}^i]} \text{ CHECK\_EXP\_AUX\_FUNCTION} \\
\\
\frac{\Delta, E, E^L \vdash exp_1 : t_1 \rightarrow t_2 \triangleright \Sigma_1^C, \Sigma_1^N \quad \Delta, E, E^L \vdash exp_2 : t_1 \triangleright \Sigma_2^C, \Sigma_2^N}{\Delta, E, E^L \vdash exp_1 \, exp_2 : t_2 \triangleright \Sigma_1^C \cup \Sigma_2^C, \Sigma_1^N \cup \Sigma_2^N} \text{ CHECK\_EXP\_AUX\_APP} \\
\\
\frac{\Delta, E, E^L \vdash (ix) : t_1 \rightarrow t_2 \rightarrow t_3 \triangleright \Sigma_1^C, \Sigma_1^N \quad \Delta, E, E^L \vdash exp_1 : t_1 \triangleright \Sigma_2^C, \Sigma_2^N \quad \Delta, E, E^L \vdash exp_2 : t_2 \triangleright \Sigma_3^C, \Sigma_3^N}{\Delta, E, E^L \vdash exp_1 \, ix \, l \, exp_2 : t_3 \triangleright \Sigma_1^C \cup \Sigma_2^C \cup \Sigma_3^C, \Sigma_1^N \cup \Sigma_2^N \cup \Sigma_3^N} \text{ CHECK\_EXP\_AUX\_INFIX\_APP1} \\
\\
\frac{\Delta, E, E^L \vdash x : t_1 \rightarrow t_2 \rightarrow t_3 \triangleright \Sigma_1^C, \Sigma_1^N \quad \Delta, E, E^L \vdash exp_1 : t_1 \triangleright \Sigma_2^C, \Sigma_2^N \quad \Delta, E, E^L \vdash exp_2 : t_2 \triangleright \Sigma_3^C, \Sigma_3^N}{\Delta, E, E^L \vdash x : t_1 \rightarrow t_2 \rightarrow t_3 \triangleright \Sigma_1^C, \Sigma_1^N} \\
\\
<<no parses (char 18): TD,E,E.1 |- exp1 '***x' 1 exp2 : t3 gives S.c1 union S.c2 union S.c3,> \\
\\
\frac{\frac{\Delta, E \vdash \mathbf{field} \, id_i : p \, t\_args \rightarrow t_i \triangleright (x_i \text{ of names})^i}{\Delta, E, E^L \vdash exp_i : t_i \triangleright \Sigma_i^C, \Sigma_i^N} \quad \mathbf{duplicates} \, (\overline{x_i}^i) = \emptyset \quad names = \{ \overline{x_i}^i \}}{\Delta, E, E^L \vdash \langle \overline{id_i} = exp_i \, l_i^i ; ? \, l \rangle : p \, t\_args \triangleright \overline{\Sigma_i^C}^i, \overline{\Sigma_i^N}^i} \text{ CHECK\_EXP\_AUX\_RECORD} \\
\\
\frac{\frac{\Delta, E \vdash \mathbf{field} \, id_i : p \, t\_args \rightarrow t_i \triangleright (x_i \text{ of names})^i}{\Delta, E, E^L \vdash exp_i : t_i \triangleright \Sigma_i^C, \Sigma_i^N} \quad \mathbf{duplicates} \, (\overline{x_i}^i) = \emptyset \quad \Delta, E, E^L \vdash exp : p \, t\_args \triangleright \Sigma^{C'}, \Sigma^{N'}}{\Delta, E, E^L \vdash \langle \overline{exp \, \mathbf{with} \, id_i = exp_i \, l_i^i ; ? \, l} \rangle : p \, t\_args \triangleright \Sigma^{C'} \cup \overline{\Sigma_i^C}^i, \Sigma^{N'} \cup \overline{\Sigma_i^N}^i} \text{ CHECK\_EXP\_AUX\_RECUP} \\
\\
\frac{\Delta, E, E^L \vdash exp_1 : t \triangleright \Sigma_1^C, \Sigma_1^N \quad \dots \quad \Delta, E, E^L \vdash exp_n : t \triangleright \Sigma_n^C, \Sigma_n^N \quad \mathbf{length} \, (exp_1 \dots exp_n) = nat}{\Delta, E, E^L \vdash [\overline{exp_1 ; \dots ; exp_n ; ?}] : \mathbf{vector} \, nat \, t \triangleright \Sigma_1^C \cup \dots \cup \Sigma_n^C, \Sigma_1^N \cup \dots \cup \Sigma_n^N} \text{ CHECK\_EXP\_AUX\_VECTOR} \\
\\
\frac{\Delta, E, E^L \vdash exp : \mathbf{vector} \, ne' \, t \triangleright \Sigma^C, \Sigma^N \quad \vdash Nexp \rightsquigarrow ne}{\Delta, E, E^L \vdash exp.(Nexp) : t \triangleright \Sigma^C, \Sigma^N \cup \{ ne \langle ne' \rangle \}} \text{ CHECK\_EXP\_AUX\_VECTORGET} \\
\\
\frac{\Delta, E, E^L \vdash exp : \mathbf{vector} \, ne' \, t \triangleright \Sigma^C, \Sigma^N \quad \vdash Nexp_1 \rightsquigarrow ne_1 \quad \vdash Nexp_2 \rightsquigarrow ne_2 \quad ne = ne_2 + (-ne_1)}{\Delta, E, E^L \vdash exp.(Nexp_1..Nexp_2) : \mathbf{vector} \, ne \, t \triangleright \Sigma^C, \Sigma^N \cup \{ ne_1 \langle ne_2 \rangle ne' \}} \text{ CHECK\_EXP\_AUX\_VECTORSUB}
\end{array}$$

$$\begin{array}{c}
\frac{
\begin{array}{l}
E \vdash \text{id} \text{ field} \\
\Delta, E \vdash \text{field } id : p \text{ } t\_args \rightarrow t \triangleright (x \text{ of } names) \\
\Delta, E, E^L \vdash exp : p \text{ } t\_args \triangleright \Sigma^C, \Sigma^N
\end{array}
}{\Delta, E, E^L \vdash exp.id : t \triangleright \Sigma^C, \Sigma^N} \text{ CHECK\_EXP\_AUX\_FIELD} \\
\\
\frac{
\frac{
\frac{
\overline{\Delta, E, E^L \vdash pat_i : t \triangleright E_i^L}^i \\
\Delta, E, E^L \uplus E_i^L \vdash exp_i : u \triangleright \Sigma_i^C, \Sigma_i^N
}{\Delta, E, E^L \vdash exp : t \triangleright \Sigma^{C'}, \Sigma^{N'}}^i \\
\Delta, E, E^L \vdash \text{match } exp \text{ with } |? \overline{pat_i \rightarrow exp_i} \overline{l_i}^i \text{ l end} : u \triangleright \Sigma^{C'} \cup \overline{\Sigma_i^C}^i, \Sigma^{N'} \cup \overline{\Sigma_i^N}^i
}{\Delta, E, E^L \vdash \text{match } exp \text{ with } |? \overline{pat_i \rightarrow exp_i} \overline{l_i}^i \text{ l end} : u \triangleright \Sigma^{C'} \cup \overline{\Sigma_i^C}^i, \Sigma^{N'} \cup \overline{\Sigma_i^N}^i} \text{ CHECK\_EXP\_AUX\_CASE} \\
\\
\frac{
\frac{
\Delta, E, E^L \vdash exp : t \triangleright \Sigma^C, \Sigma^N \\
\Delta, E \vdash typ \rightsquigarrow t
}{\Delta, E, E^L \vdash (exp : typ) : t \triangleright \Sigma^C, \Sigma^N} \text{ CHECK\_EXP\_AUX\_TYPED} \\
\\
\frac{
\frac{
\Delta, E, E_1^L \vdash letbind \triangleright E_2^L, \Sigma_1^C, \Sigma_1^N \\
\Delta, E, E_1^L \uplus E_2^L \vdash exp : t \triangleright \Sigma_2^C, \Sigma_2^N
}{\Delta, E, E_1^L \vdash \text{let } letbind \text{ in } exp : t \triangleright \Sigma_1^C \cup \Sigma_2^C, \Sigma_1^N \cup \Sigma_2^N} \text{ CHECK\_EXP\_AUX\_LET} \\
\\
\frac{
\Delta, E, E^L \vdash exp_1 : t_1 \triangleright \Sigma_1^C, \Sigma_1^N \quad \dots \quad \Delta, E, E^L \vdash exp_n : t_n \triangleright \Sigma_n^C, \Sigma_n^N
}{\Delta, E, E^L \vdash (exp_1, \dots, exp_n) : t_1 * \dots * t_n \triangleright \Sigma_1^C \cup \dots \cup \Sigma_n^C, \Sigma_1^N \cup \dots \cup \Sigma_n^N} \text{ CHECK\_EXP\_AUX\_TUP} \\
\\
\frac{
\Delta \vdash t \text{ ok} \\
\Delta, E, E^L \vdash exp_1 : t \triangleright \Sigma_1^C, \Sigma_1^N \quad \dots \quad \Delta, E, E^L \vdash exp_n : t \triangleright \Sigma_n^C, \Sigma_n^N
}{\Delta, E, E^L \vdash [exp_1; \dots; exp_n; ?] : \_list t \triangleright \Sigma_1^C \cup \dots \cup \Sigma_n^C, \Sigma_1^N \cup \dots \cup \Sigma_n^N} \text{ CHECK\_EXP\_AUX\_LIST} \\
\\
\frac{
\Delta, E, E^L \vdash exp : t \triangleright \Sigma^C, \Sigma^N
}{\Delta, E, E^L \vdash (exp) : t \triangleright \Sigma^C, \Sigma^N} \text{ CHECK\_EXP\_AUX\_PAREN} \\
\\
\frac{
\Delta, E, E^L \vdash exp : t \triangleright \Sigma^C, \Sigma^N
}{\Delta, E, E^L \vdash \text{begin } exp \text{ end} : t \triangleright \Sigma^C, \Sigma^N} \text{ CHECK\_EXP\_AUX\_BEGIN} \\
\\
\frac{
\frac{
\Delta, E, E^L \vdash exp_1 : \_bool \triangleright \Sigma_1^C, \Sigma_1^N \\
\Delta, E, E^L \vdash exp_2 : t \triangleright \Sigma_2^C, \Sigma_2^N \\
\Delta, E, E^L \vdash exp_3 : t \triangleright \Sigma_3^C, \Sigma_3^N
}{\Delta, E, E^L \vdash \text{if } exp_1 \text{ then } exp_2 \text{ else } exp_3 : t \triangleright \Sigma_1^C \cup \Sigma_2^C \cup \Sigma_3^C, \Sigma_1^N \cup \Sigma_2^N \cup \Sigma_3^N} \text{ CHECK\_EXP\_AUX\_IF} \\
\\
\frac{
\frac{
\Delta, E, E^L \vdash exp_1 : t \triangleright \Sigma_1^C, \Sigma_1^N \\
\Delta, E, E^L \vdash exp_2 : \_list t \triangleright \Sigma_2^C, \Sigma_2^N
}{\Delta, E, E^L \vdash exp_1 :: exp_2 : \_list t \triangleright \Sigma_1^C \cup \Sigma_2^C, \Sigma_1^N \cup \Sigma_2^N} \text{ CHECK\_EXP\_AUX\_CONS} \\
\\
\frac{
\vdash lit : t
}{\Delta, E, E^L \vdash lit : t \triangleright \{\}, \{\}} \text{ CHECK\_EXP\_AUX\_LIT} \\
\\
\frac{
\frac{
\overline{\Delta \vdash t_i \text{ ok}}^i \\
\Delta, E, E^L \uplus \{ \overline{x_i \mapsto t_i}^i \} \vdash exp_1 : t \triangleright \Sigma_1^C, \Sigma_1^N \\
\Delta, E, E^L \uplus \{ \overline{x_i \mapsto t_i}^i \} \vdash exp_2 : \_bool \triangleright \Sigma_2^C, \Sigma_2^N \\
\text{disjoint doms}(E^L, \{ \overline{x_i \mapsto t_i}^i \}) \\
E = \langle E^M, E^P, E^F, E^X \rangle \\
\overline{x_i \notin \text{dom}(E^X)}^i
}{\Delta, E, E^L \vdash \{ exp_1 | exp_2 \} : \_set t \triangleright \Sigma_1^C \cup \Sigma_2^C, \Sigma_1^N \cup \Sigma_2^N} \text{ CHECK\_EXP\_AUX\_SET\_COMP} \\
\\
\frac{
\frac{
\Delta, E, E_1^L \vdash \overline{qbind_i}^i \triangleright E_2^L, \Sigma_1^C \\
\Delta, E, E_1^L \uplus E_2^L \vdash exp_1 : t \triangleright \Sigma_2^C, \Sigma_2^N \\
\Delta, E, E_1^L \uplus E_2^L \vdash exp_2 : \_bool \triangleright \Sigma_3^C, \Sigma_3^N
}{\Delta, E, E_1^L \vdash \{ exp_1 | \text{forall } \overline{qbind_i}^i | exp_2 \} : \_set t \triangleright \Sigma_1^C \cup \Sigma_2^C \cup \Sigma_3^C, \Sigma_2^N \cup \Sigma_3^N} \text{ CHECK\_EXP\_AUX\_SET\_COMP}
\end{array}$$

$$\frac{\Delta \vdash t \text{ ok} \quad \Delta, E, E^L \vdash \text{exp}_1 : t \triangleright \Sigma^C_1, \Sigma^N_1 \quad \dots \quad \Delta, E, E^L \vdash \text{exp}_n : t \triangleright \Sigma^C_n, \Sigma^N_n}{\Delta, E, E^L \vdash \{\text{exp}_1; \dots; \text{exp}_n; ?\} : \text{--set } t \triangleright \Sigma^C_1 \cup \dots \cup \Sigma^C_n, \Sigma^N_1 \cup \dots \cup \Sigma^N_n} \text{ CHECK\_EXP\_AUX\_SET}$$

$$\frac{\Delta, E, E^L_1 \vdash \overline{qbind_i}^i \triangleright E^L_2, \Sigma^C_1 \quad \Delta, E, E^L_1 \uplus E^L_2 \vdash \text{exp} : \text{--bool} \triangleright \Sigma^C_2, \Sigma^N_2}{\Delta, E, E^L_1 \vdash q \overline{qbind_i}^i . \text{exp} : \text{--bool} \triangleright \Sigma^C_1 \cup \Sigma^C_2, \Sigma^N_2} \text{ CHECK\_EXP\_AUX\_QUANT}$$

$$\frac{\Delta, E, E^L_1 \vdash \text{list } \overline{qbind_i}^i \triangleright E^L_2, \Sigma^C_1 \quad \Delta, E, E^L_1 \uplus E^L_2 \vdash \text{exp}_1 : t \triangleright \Sigma^C_2, \Sigma^N_2 \quad \Delta, E, E^L_1 \uplus E^L_2 \vdash \text{exp}_2 : \text{--bool} \triangleright \Sigma^C_3, \Sigma^N_3}{\Delta, E, E^L_1 \vdash [\text{exp}_1 | \text{forall } \overline{qbind_i}^i | \text{exp}_2] : \text{--list } t \triangleright \Sigma^C_1 \cup \Sigma^C_2 \cup \Sigma^C_3, \Sigma^N_2 \cup \Sigma^N_3} \text{ CHECK\_EXP\_AUX\_LIST\_COMP}$$

$$\boxed{\Delta, E, E^L_1 \vdash qbind_1 \dots qbind_n \triangleright E^L_2, \Sigma^C} \quad \text{Build the environment for quantifier bindings, collecting typeclass cons}$$

$$\overline{\Delta, E, E^L \vdash \triangleright \{\}, \{\}} \quad \text{CHECK\_LISTQUANT\_BINDING\_EMPTY}$$

$$\frac{\Delta \vdash t \text{ ok} \quad \Delta, E, E^L_1 \uplus \{x \mapsto t\} \vdash \overline{qbind_i}^i \triangleright E^L_2, \Sigma^C_1 \quad \text{disjoint doms}(\{x \mapsto t\}, E^L_2)}{\Delta, E, E^L_1 \vdash x \overline{qbind_i}^i \triangleright \{x \mapsto t\} \uplus E^L_2, \Sigma^C_1} \text{ CHECK\_LISTQUANT\_BINDING\_VAR}$$

$$\frac{\Delta, E, E^L_1 \vdash \text{pat} : t \triangleright E^L_3 \quad \Delta, E, E^L_1 \vdash \text{exp} : \text{--set } t \triangleright \Sigma^C_1, \Sigma^N_1 \quad \Delta, E, E^L_1 \uplus E^L_3 \vdash \overline{qbind_i}^i \triangleright E^L_2, \Sigma^C_2 \quad \text{disjoint doms}(E^L_3, E^L_2)}{\Delta, E, E^L_1 \vdash (\text{pat } \text{IN } \text{exp}) \overline{qbind_i}^i \triangleright E^L_2 \uplus E^L_3, \Sigma^C_1 \cup \Sigma^C_2} \text{ CHECK\_LISTQUANT\_BINDING\_RESTR}$$

$$\frac{\Delta, E, E^L_1 \vdash \text{pat} : t \triangleright E^L_3 \quad \Delta, E, E^L_1 \vdash \text{exp} : \text{--list } t \triangleright \Sigma^C_1, \Sigma^N_1 \quad \Delta, E, E^L_1 \uplus E^L_3 \vdash \overline{qbind_i}^i \triangleright E^L_2, \Sigma^C_2 \quad \text{disjoint doms}(E^L_3, E^L_2)}{\Delta, E, E^L_1 \vdash (\text{pat } \text{MEM } \text{exp}) \overline{qbind_i}^i \triangleright E^L_2 \uplus E^L_3, \Sigma^C_1 \cup \Sigma^C_2} \text{ CHECK\_LISTQUANT\_BINDING\_LIST\_RESTR}$$

$$\boxed{\Delta, E, E^L_1 \vdash \text{list } qbind_1 \dots qbind_n \triangleright E^L_2, \Sigma^C} \quad \text{Build the environment for quantifier bindings, collecting typeclass}$$

$$\overline{\Delta, E, E^L \vdash \text{list} \triangleright \{\}, \{\}} \quad \text{CHECK\_QUANT\_BINDING\_EMPTY}$$

$$\frac{\Delta, E, E^L_1 \vdash \text{pat} : t \triangleright E^L_3 \quad \Delta, E, E^L_1 \vdash \text{exp} : \text{--list } t \triangleright \Sigma^C_1, \Sigma^N_1 \quad \Delta, E, E^L_1 \uplus E^L_3 \vdash \overline{qbind_i}^i \triangleright E^L_2, \Sigma^C_2 \quad \text{disjoint doms}(E^L_3, E^L_2)}{\Delta, E, E^L_1 \vdash \text{list } (\text{pat } \text{MEM } \text{exp}) \overline{qbind_i}^i \triangleright E^L_2 \uplus E^L_3, \Sigma^C_1 \cup \Sigma^C_2} \text{ CHECK\_QUANT\_BINDING\_RESTR}$$

$$\boxed{\Delta, E, E^L \vdash \text{funcl} \triangleright \{x \mapsto t\}, \Sigma^C, \Sigma^N} \quad \text{Build the environment for a function definition clause, collecting typeclass}$$

$$\frac{\Delta, E, E^L \vdash \text{pat}_1 : t_1 \triangleright E^L_1 \quad \dots \quad \Delta, E, E^L \vdash \text{pat}_n : t_n \triangleright E^L_n \quad \Delta, E, E^L \uplus E^L_1 \uplus \dots \uplus E^L_n \vdash \text{exp} : u \triangleright \Sigma^C, \Sigma^N \quad \text{disjoint doms}(E^L_1, \dots, E^L_n) \quad \Delta, E \vdash \text{typ} \rightsquigarrow u}{\Delta, E, E^L \vdash x \text{ l}_1 \text{ pat}_1 \dots \text{pat}_n : \text{typ} = \text{exp } l_2 \triangleright \{x \mapsto \text{curry}((t_1 * \dots * t_n), u)\}, \Sigma^C, \Sigma^N} \text{ CHECK\_FUNCL\_ANNOT}$$

$$\begin{array}{c}
\Delta, E, E^L \vdash pat_1 : t_1 \triangleright E_1^L \quad \dots \quad \Delta, E, E^L \vdash pat_n : t_n \triangleright E_n^L \\
\Delta, E, E^L \uplus E_1^L \uplus \dots \uplus E_n^L \vdash exp : u \triangleright \Sigma^C, \Sigma^N \\
\text{disjoint doms } (E_1^L, \dots, E_n^L) \\
\hline
\Delta, E, E^L \vdash x \, l_1 \, pat_1 \dots pat_n = exp \, l_2 \triangleright \{x \mapsto \mathbf{curry}((t_1 * \dots * t_n), u)\}, \Sigma^C, \Sigma^N \quad \text{CHECK\_FUNCL\_NOANNOT} \\
\boxed{\Delta, E, E_1^L \vdash letbind \triangleright E_2^L, \Sigma^C, \Sigma^N} \quad \text{Build the environment for a let binding, collecting typeclass and index con} \\
\begin{array}{c}
\Delta, E, E_1^L \vdash pat : t \triangleright E_2^L \\
\Delta, E, E_1^L \vdash exp : t \triangleright \Sigma^C, \Sigma^N \\
\Delta, E \vdash typ \rightsquigarrow t \\
\hline
\Delta, E, E_1^L \vdash pat : typ = exp \, l \triangleright E_2^L, \Sigma^C, \Sigma^N \quad \text{CHECK\_LETBIND\_VAL\_ANNOT}
\end{array} \\
\begin{array}{c}
\Delta, E, E_1^L \vdash pat : t \triangleright E_2^L \\
\Delta, E, E_1^L \vdash exp : t \triangleright \Sigma^C, \Sigma^N \\
\hline
\Delta, E, E_1^L \vdash pat = exp \, l \triangleright E_2^L, \Sigma^C, \Sigma^N \quad \text{CHECK\_LETBIND\_VAL\_NOANNOT}
\end{array} \\
\begin{array}{c}
\Delta, E, E_1^L \vdash funcl\_aux \, l \triangleright \{x \mapsto t\}, \Sigma^C, \Sigma^N \\
\hline
\Delta, E, E_1^L \vdash funcl\_aux \, l \triangleright \{x \mapsto t\}, \Sigma^C, \Sigma^N \quad \text{CHECK\_LETBIND\_FN}
\end{array} \\
\boxed{\Delta, E, E^L \vdash rule \triangleright \{x \mapsto t\}, \Sigma^C, \Sigma^N} \quad \text{Build the environment for an inductive relation clause, collecting typecl} \\
\begin{array}{c}
\overline{\Delta \vdash t_i \mathbf{ok}}^i \\
E_2^L = \{ \overline{name\_t_i \rightarrow x \mapsto t_i}^i \} \\
\Delta, E, E_1^L \uplus E_2^L \vdash exp' : \_ \mathbf{bool} \triangleright \Sigma^{C'}, \Sigma^{N'} \\
\Delta, E, E_1^L \uplus E_2^L \vdash exp_1 : u_1 \triangleright \Sigma_1^C, \Sigma_1^{N'} \quad \dots \quad \Delta, E, E_1^L \uplus E_2^L \vdash exp_n : u_n \triangleright \Sigma_n^C, \Sigma_n^{N'} \\
\hline
\Delta, E, E_1^L \vdash x_1^l : \mathbf{forall} \, \overline{name\_t_i}^i . exp' \implies x \, l \, exp_1 \dots exp_n \, l' \triangleright \{x \mapsto \mathbf{curry}((u_1 * \dots * u_n), \_ \mathbf{bool})\}, \Sigma^{C'} \cup \Sigma_1^C \cup \dots
\end{array} \\
\boxed{xs, \Delta_1, E \vdash \mathbf{tc} \, td \triangleright \Delta_2, E^P} \quad \text{Extract the type constructor information} \\
\begin{array}{c}
tnvars^l \rightsquigarrow tnvs \\
\Delta, E \vdash typ \rightsquigarrow t \\
\mathbf{duplicates}(tnvs) = \emptyset \\
\mathbf{FV}(t) \subset tnvs \\
\overline{y_i}^i x \notin \mathbf{dom}(\Delta) \\
\hline
\overline{y_i}^i, \Delta, E \vdash \mathbf{tc} \, x \, l \, tnvars^l = typ \triangleright \{ \overline{y_i}^i x \mapsto tnvs.t \}, \{x \mapsto \overline{y_i}^i x\} \quad \text{CHECK\_TEXP\_TC\_ABBREV}
\end{array} \\
\begin{array}{c}
tnvars^l \rightsquigarrow tnvs \\
\mathbf{duplicates}(tnvs) = \emptyset \\
\overline{y_i}^i x \notin \mathbf{dom}(\Delta) \\
\hline
\overline{y_i}^i, \Delta, E_1 \vdash \mathbf{tc} \, x \, l \, tnvars^l \triangleright \{ \overline{y_i}^i x \mapsto tnvs \}, \{x \mapsto \overline{y_i}^i x\} \quad \text{CHECK\_TEXP\_TC\_ABSTRACT}
\end{array} \\
\begin{array}{c}
tnvars^l \rightsquigarrow tnvs \\
\mathbf{duplicates}(tnvs) = \emptyset \\
\overline{y_i}^i x \notin \mathbf{dom}(\Delta) \\
\hline
\overline{y_i}^i, \Delta_1, E \vdash \mathbf{tc} \, x \, l \, tnvars^l = \langle |x_1^l : typ_1; \dots; x_j^l : typ_j; ?| \rangle \triangleright \{ \overline{y_i}^i x \mapsto tnvs \}, \{x \mapsto \overline{y_i}^i x\} \quad \text{CHECK\_TEXP\_TC\_REC}
\end{array} \\
\begin{array}{c}
tnvars^l \rightsquigarrow tnvs \\
\mathbf{duplicates}(tnvs) = \emptyset \\
\overline{y_i}^i x \notin \mathbf{dom}(\Delta) \\
\hline
\overline{y_i}^i, \Delta_1, E \vdash \mathbf{tc} \, x \, l \, tnvars^l = |? \, ctor\_def_1| \dots |ctor\_def_j| \triangleright \{ \overline{y_i}^i x \mapsto tnvs \}, \{x \mapsto \overline{y_i}^i x\} \quad \text{CHECK\_TEXP\_TC\_VAR}
\end{array} \\
\boxed{xs, \Delta_1, E \vdash \mathbf{tc} \, td_1 \dots td_i \triangleright \Delta_2, E^P} \quad \text{Extract the type constructor information} \\
\overline{xs, \Delta, E \vdash \mathbf{tc} \triangleright \{ \}, \{ \}} \quad \text{CHECK\_TEXPS\_TC\_EMPTY}
\end{array}$$

$$\begin{array}{c}
xs, \Delta_1, E \vdash \mathbf{tc} \, td \triangleright \Delta_2, E_2^P \\
xs, \Delta_1 \uplus \Delta_2, E \uplus \langle \{ \}, E_2^P, \{ \}, \{ \} \rangle \vdash \mathbf{tc} \, \overline{td_i}^i \triangleright \Delta_3, E_3^P \\
\mathbf{dom}(E_2^P) \cap \mathbf{dom}(E_3^P) = \emptyset \\
\hline
xs, \Delta_1, E \vdash \mathbf{tc} \, td \, \overline{td_i}^i \triangleright \Delta_2 \uplus \Delta_3, E_2^P \uplus E_3^P
\end{array}
\quad \text{CHECK\_TEXPS\_TC\_ABBREV}$$

$$\boxed{\Delta, E \vdash tnvs \, p = texp \triangleright \langle E^F, E^X \rangle} \quad \text{Check a type definition, with its path already resolved}$$

$$\overline{\Delta, E \vdash tnvs \, p = typ \triangleright \langle \{ \}, \{ \} \rangle} \quad \text{CHECK\_TEXP\_ABBREV}$$

$$\begin{array}{c}
\overline{\Delta, E \vdash typ_i \rightsquigarrow t_i^i} \\
names = \{ \overline{x_i}^i \} \\
\mathbf{duplicates}(\overline{x_i}^i) = \emptyset \\
\mathbf{FV}(t_i) \subset tnvs^i \\
E^F = \{ x_i \mapsto \langle \mathbf{forall} \, tnvs.p \rightarrow t_i, (x_i \mathbf{of} \, names) \rangle^i \} \\
\hline
\Delta, E \vdash tnvs \, p = \langle | \overline{x_i^l} : typ_i^l ; ? | \rangle \triangleright \langle E^F, \{ \} \rangle
\end{array}
\quad \text{CHECK\_TEXP\_REC}$$

$$\begin{array}{c}
\overline{\Delta, E \vdash typs_i \rightsquigarrow t\_multi_i^i} \\
names = \{ \overline{x_i}^i \} \\
\mathbf{duplicates}(\overline{x_i}^i) = \emptyset \\
\mathbf{FV}(t\_multi_i) \subset tnvs^i \\
E^X = \{ x_i \mapsto \langle \mathbf{forall} \, tnvs.t\_multi_i \rightarrow p, (x_i \mathbf{of} \, names) \rangle^i \} \\
\hline
\Delta, E \vdash tnvs \, p = | ? \overline{x_i^l} \mathbf{of} \, typs_i^l | \triangleright \langle \{ \}, E^X \rangle
\end{array}
\quad \text{CHECK\_TEXP\_VAR}$$

$$\boxed{xs, \Delta, E \vdash td_1 \dots td_n \triangleright \langle E^F, E^X \rangle}$$

$$\overline{\overline{y_i}^i, \Delta, E \vdash \triangleright \langle \{ \}, \{ \} \rangle} \quad \text{CHECK\_TEXPS\_EMPTY}$$

$$\begin{array}{c}
tnvars^l \rightsquigarrow tnvs \\
\Delta, E_1 \vdash tnvs \, \overline{y_i}^i \, x = texp \triangleright \langle E_1^F, E_1^X \rangle \\
\overline{y_i}^i, \Delta, E \vdash \overline{td_j}^j \triangleright \langle E_2^F, E_2^X \rangle \\
\mathbf{dom}(E_1^X) \cap \mathbf{dom}(E_2^X) = \emptyset \\
\mathbf{dom}(E_1^F) \cap \mathbf{dom}(E_2^F) = \emptyset \\
\hline
\overline{\overline{y_i}^i, \Delta, E \vdash x \, l \, tnvars^l = texp \, \overline{td_j}^j \triangleright \langle E_1^F \uplus E_2^F, E_1^X \uplus E_2^X \rangle}
\end{array}
\quad \text{CHECK\_TEXPS\_CONS\_CONCRETE}$$

$$\begin{array}{c}
\overline{\overline{y_i}^i, \Delta, E \vdash \overline{td_j}^j \triangleright \langle E^F, E^X \rangle} \\
\hline
\overline{\overline{y_i}^i, \Delta, E \vdash x \, l \, tnvars^l \, \overline{td_j}^j \triangleright \langle E^F, E^X \rangle}
\end{array}
\quad \text{CHECK\_TEXPS\_CONS\_ABSTRACT}$$

$$\boxed{\delta, E \vdash id \rightsquigarrow p} \quad \text{Lookup a type class}$$

$$\begin{array}{c}
E(id) \triangleright p \\
\delta(p) \triangleright xs \\
\hline
\delta, E \vdash id \rightsquigarrow p
\end{array}
\quad \text{CONVERT\_CLASS\_ALL}$$

$$\boxed{I \vdash (p \, t) \mathbf{INC}} \quad \text{Solve class constraint}$$

$$\begin{array}{c}
\overline{I \vdash (p \, \alpha) \mathbf{IN} (p_1 \, tnvs_1) \dots (p_i \, tnvs_i) (p \, \alpha) (p'_1 \, tnvs'_1) \dots (p'_j \, tnvs'_j)} \\
\hline
\overline{\begin{array}{c} (p_1 \, tnvs_1) \dots (p_n \, tnvs_n) \Rightarrow (p \, t) \mathbf{IN} \, I \\ I \vdash (p_1 \, \sigma(tnvs_1)) \mathbf{INC} \dots I \vdash (p_n \, \sigma(tnvs_n)) \mathbf{INC} \end{array}} \\
\hline
I \vdash (p \, \sigma(t)) \mathbf{INC}
\end{array}
\quad \begin{array}{l} \text{SOLVE\_CLASS\_CONSTRAINT\_IMMEDIATE} \\ \text{SOLVE\_CLASS\_CONSTRAINT\_CHAIN} \end{array}$$

$I \vdash \Sigma^C \triangleright C$  Solve class constraints

$$\frac{I \vdash (p_1 t_1) \mathbf{INC} \quad \dots \quad I \vdash (p_n t_n) \mathbf{INC}}{I \vdash \{(p_1 t_1), \dots, (p_n t_n)\} \triangleright C} \text{SOLVE\_CLASS\_CONSTRAINTS\_ALL}$$

$\Delta, I, E \vdash \text{val\_def} \triangleright E^X$  Check a value definition

$$\frac{\begin{array}{l} \Delta, E, \{\} \vdash \text{letbind} \triangleright \{\overline{x_i \mapsto t_i^i}\}, \Sigma^C, \Sigma^N \\ I \vdash \Sigma^C \triangleright C \\ \overline{\mathbf{FV}(t_i) \subset \text{tnvs}}^i \\ \mathbf{FV}(C) \subset \text{tnvs} \end{array}}{\Delta, I, E_1 \vdash \text{let } \tau^? \text{ letbind} \triangleright \{\overline{x_i \mapsto \langle \text{forall tnvs.C} \Rightarrow t_i, \text{let} \rangle^i}\}} \text{CHECK\_VAL\_DEF\_VAL}$$

$$\frac{\begin{array}{l} \Delta, E, E^L \vdash \text{funcl}_i \triangleright \{\overline{x_i \mapsto t_i}\}, \Sigma_i^C, \Sigma_i^N^i \\ I \vdash \Sigma^C \triangleright C \\ \overline{\mathbf{FV}(t_i) \subset \text{tnvs}}^i \\ \mathbf{FV}(C) \subset \text{tnvs} \\ \text{compatible overlap}(\overline{x_i \mapsto t_i^i}) \\ E^L = \{\overline{x_i \mapsto t_i^i}\} \end{array}}{\Delta, I, E \vdash \text{let rec } \tau^? \text{ funcl}_i^i \triangleright \{\overline{x_i \mapsto \langle \text{forall tnvs.C} \Rightarrow t_i, \text{let} \rangle^i}\}} \text{CHECK\_VAL\_DEF\_RECFUN}$$

$\Delta, (\alpha_1, \dots, \alpha_n) \vdash t \mathbf{instance}$  Check that  $t$  be a typeclass instance

$$\overline{\Delta, (\alpha) \vdash \alpha \mathbf{instance}} \text{CHECK\_T\_INSTANCE\_VAR}$$

$$\overline{\Delta, (\alpha_1, \dots, \alpha_n) \vdash \alpha_1 * \dots * \alpha_n \mathbf{instance}} \text{CHECK\_T\_INSTANCE\_TUP}$$

$$\overline{\Delta, (\alpha_1, \alpha_2) \vdash \alpha_1 \rightarrow \alpha_n \mathbf{instance}} \text{CHECK\_T\_INSTANCE\_FN}$$

$$\frac{\Delta(p) \triangleright \alpha'_1 \dots \alpha'_n}{\Delta, (\alpha_1, \dots, \alpha_n) \vdash p \alpha_1 \dots \alpha_n \mathbf{instance}} \text{CHECK\_T\_INSTANCE\_TC}$$

$\overline{\overline{z_j^j}, D_1, E_1 \vdash \text{def} \triangleright D_2, E_2}$  Check a definition

$$\frac{\begin{array}{l} \overline{z_j^j}, \Delta_1, E \vdash \mathbf{tc} \overline{td_i^i} \triangleright \Delta_2, E^P \\ \overline{z_j^j}, \Delta_1 \uplus \Delta_2, E \uplus \langle \{\}, E^P, \{\}, \{\} \rangle \vdash \overline{td_i^i} \triangleright \langle E^F, E^X \rangle \end{array}}{\overline{z_j^j}, \langle \Delta_1, \delta, I \rangle, E \vdash \mathbf{type} \overline{td_i^i} l \triangleright \langle \Delta_2, \{\}, \{\}, \langle \{\}, E^P, E^F, E^X \rangle \rangle} \text{CHECK\_DEF\_TYPE}$$

$$\frac{\Delta, I, E \vdash \text{val\_def} \triangleright E^X}{\overline{\overline{z_j^j}, \langle \Delta, \delta, I \rangle, E \vdash \text{val\_def} l \triangleright \epsilon, \langle \{\}, \{\}, \{\}, E^X \rangle}} \text{CHECK\_DEF\_VAL\_DEF}$$

$$\frac{\begin{array}{l} \Delta, E_1, E^L \vdash \text{rule}_i \triangleright \{\overline{x_i \mapsto t_i}\}, \Sigma_i^C, \Sigma_i^N^i \\ I \vdash \overline{\Sigma_i^C}^i \triangleright C \\ \overline{\mathbf{FV}(t_i) \subset \text{tnvs}}^i \\ \mathbf{FV}(C) \subset \text{tnvs} \\ \text{compatible overlap}(\overline{x_i \mapsto t_i^i}) \\ E^L = \{\overline{x_i \mapsto t_i^i}\} \\ E_2 = \langle \{\}, \{\}, \{\}, \{\overline{x_i \mapsto \langle \text{forall tnvs.C} \Rightarrow t_i, \text{let} \rangle^i}\} \rangle \end{array}}$$

<<no parses (char 59): </zj//j/>,<TD,TC,I>,E1 |- indreln targets\_opt indreln\_names\*\*\* </rule>

$$\frac{\overline{z_j}^j x, D_1, E_1 \vdash \text{defs} \triangleright D_2, E_2}{\overline{z_j}^j, D_1, E_1 \vdash \mathbf{module} \ x \ l_1 = \mathbf{struct} \ \text{defs} \ \mathbf{end} \ l_2 \triangleright D_2, \langle \{x \mapsto E_2\}, \{\}, \{\}, \{\} \rangle} \text{CHECK\_DEF\_MODULE}$$

$$\frac{E_1(id) \triangleright E_2}{\overline{z_j}^j, D, E_1 \vdash \mathbf{module} \ x \ l_1 = id \ l_2 \triangleright \epsilon, \langle \{x \mapsto E_2\}, \{\}, \{\}, \{\} \rangle} \text{CHECK\_DEF\_MODULE\_RENAME}$$

$$\frac{\begin{array}{l} \Delta, E \vdash \text{typ} \rightsquigarrow t \\ \mathbf{FV}(t) \subset \overline{\alpha_i}^i \\ \mathbf{FV}(\overline{\alpha'_k}^k) \subset \overline{\alpha_i}^i \\ \overline{\delta, E \vdash id_k \rightsquigarrow p_k}^k \\ E' = \langle \{\}, \{\}, \{\}, \{x \mapsto \langle \mathbf{forall} \ \overline{\alpha_i}^i. (\overline{p_k} \ \overline{\alpha'_k})^k \Rightarrow t, \mathbf{val} \rangle\} \rangle \end{array}}{\overline{z_j}^j, \langle \Delta, \delta, I \rangle, E \vdash \mathbf{val} \ x \ l_1 : \mathbf{forall} \ \overline{\alpha_i}^i \ l_i''^i. \overline{id_k} \ \overline{\alpha'_k} \ l_k''^k \Rightarrow \text{typ} \ l_2 \triangleright \epsilon, E'} \text{CHECK\_DEF\_SPEC}$$

$$\frac{\begin{array}{l} \overline{\Delta, E_1 \vdash \text{typ}_i \rightsquigarrow t_i}^i \\ \mathbf{FV}(t_i) \subset \overline{\alpha}^i \\ p = \overline{z_j}^j x \\ E_2 = \langle \{\}, \{x \mapsto p\}, \{\}, \{y_i \mapsto \langle \mathbf{forall} \ \alpha. (p \ \alpha) \Rightarrow t_i, \mathbf{method} \rangle^i\} \rangle \\ \delta_2 = \{p \mapsto \overline{y_i}^i\} \\ p \notin \mathbf{dom}(\delta_1) \end{array}}{\overline{z_j}^j, \langle \Delta, \delta_1, I \rangle, E_1 \vdash \mathbf{class}(x \ l \ \alpha \ l'') \ \mathbf{val} \ y_i \ l_i : \text{typ}_i \ l_i^i \ \mathbf{end} \ l' \triangleright \langle \{\}, \delta_2, \{\} \rangle, E_2} \text{CHECK\_DEF\_CLASS}$$

$$\frac{\begin{array}{l} E = \langle E^M, E^P, E^F, E^X \rangle \\ \Delta, E \vdash \text{typ}' \rightsquigarrow t' \\ \Delta, (\overline{\alpha_i}^i) \vdash t' \mathbf{instance} \\ tnvs = \overline{\alpha_i}^i \\ \mathbf{duplicates}(tnvs) = \emptyset \\ \overline{\delta, E \vdash id_k \rightsquigarrow p_k}^k \\ \mathbf{FV}(\overline{\alpha'_k}^k) \subset tnvs \\ E(id) \triangleright p \\ \delta(p) \triangleright \overline{z_j}^j \\ I_2 = \{ \Rightarrow (\overline{p_k} \ \overline{\alpha'_k})^k \} \\ \overline{\Delta, I \cup I_2, E \vdash \text{val\_def}_n \triangleright E_n^X}^n \\ \mathbf{disjoint} \ \mathbf{doms}(\overline{E_n^X}^n) \\ \overline{E^X(x_k) \triangleright \langle \mathbf{forall} \ \alpha''. (p \ \alpha'') \Rightarrow t_k, \mathbf{method} \rangle^k}^k \\ \overline{\{x_k \mapsto \langle \mathbf{forall} \ tnvs. \Rightarrow \{\alpha'' \mapsto t'\}(t_k), \mathbf{let} \rangle^k\}}^k = \overline{E_n^X}^n \\ \overline{x_k}^k = \overline{z_j}^j \\ I_3 = \{ \overline{(p_k \ \alpha'_k) \Rightarrow (p \ t')}^k \} \\ (p \{ \overline{\alpha_i \mapsto \alpha_i''}^i \}(t')) \notin I \end{array}}{\overline{z_j}^j, \langle \Delta, \delta, I \rangle, E \vdash \mathbf{instance} \ \mathbf{forall} \ \overline{\alpha_i}^i \ l_i''^i. \overline{id_k} \ \overline{\alpha'_k} \ l_k''^k \Rightarrow (id \ \text{typ}') \ \overline{\text{val\_def}_n} \ l_n^n \ \mathbf{end} \ l' \triangleright \langle \{\}, \{\}, I_3 \rangle, \epsilon} \text{CHECK\_DEF\_...}$$

$\overline{z_j}^j, D_1, E_1 \vdash \text{defs} \triangleright D_2, E_2$

Check definitions, given module path, definitions and environment

$$\overline{\overline{z_j}^j, D, E \vdash \triangleright \epsilon, \epsilon} \text{CHECK\_DEFS\_EMPTY}$$

$$\frac{\begin{array}{l} \overline{z_j}^j, D_1, E_1 \vdash \text{def} \triangleright D_2, E_2 \\ \overline{z_j}^j, D_1 \uplus D_2, E_1 \uplus E_2 \vdash \overline{\text{def}_i; ;_i^?}^i \triangleright D_3, E_3 \end{array}}{\overline{z_j}^j, D_1, E_1 \vdash \text{def}; ;_i^? \overline{\text{def}_i; ;_i^?}^i \triangleright D_2 \uplus D_3, E_2 \uplus E_3} \text{CHECK\_DEFS\_RELEVANT\_DEF}$$

$$\frac{
\begin{array}{c}
E_1(id) \triangleright E_2 \\
\overline{z_j^j}, D_1, E_1 \uplus E_2 \vdash \overline{def_i ; ; ; ?^i_i} \triangleright D_3, E_3
\end{array}
}{
\overline{z_j^j}, D_1, E_1 \vdash \mathbf{open} \, id \, l ; ; ?^i \overline{def_i ; ; ; ?^i_i} \triangleright D_3, E_3
} \quad \text{CHECK\_DEFS\_OPEN}$$

Definition rules: 143 good 2 bad  
Definition rule clauses: 437 good 2 bad