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

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

Nexp	::=		Location-annotated vector lengths
	|	*Nexp_aux l*	
Nexp_constraint_aux	::=		Whether a vector is bounded or fixed size
	|	$Nexp = Nexp'$	
	|	$Nexp \geq Nexp'$	
Nexp_constraint	::=		Location-annotated Nexp range
	|	*Nexp_constraint_aux l*	
typ_aux	::=		Types
	|	_	Unspecified type
	|	α^l	Type variables
	|	$typ_1 \rightarrow typ_2$	Function types
	|	$typ_1 * .... * typ_n$	Tuple types
	|	*Nexp*	As a typ to permit applications over Nexps, other
	|	$id\ typ_1 .. typ_n$	Type applications
	|	(typ)	
typ	::=		Location-annotated types
	|	*typ_aux l*	
lit_aux	::=		Literal constants
	|	**true**	
	|	**false**	
	|	*num*	
	|	*hex*	hex and bin are constant bit vectors, entered as C
	|	*bin*	
	|	*string*	
	|	()	
	|	**bitzero**	bitzero and bitone are constant bits, if commonly
	|	**bitone**	
lit	::=		
	|	*lit_aux l*	Location-annotated literal constants
$;^?$	::=		Optional semi-colons
	|		
	|	;	
pat_aux	::=		Patterns
	|	_	Wildcards
	|	$(pat\ \mathbf{as}\ x^l)$	Named patterns
	|	$(pat : typ)$	Typed patterns
	|	$id\ pat_1 .. pat_n$	Single variable and constructor patterns
	|	$\langle\|fpat_1; ... ; fpat_n\ ;^?\|\rangle$	Record patterns
	|	$[\|pat_1; .. ; pat_n\ ;^?\|]$	Vector patterns

	$[\|pat_1 \,..\, pat_n\|]$	Concatenated vector patterns
	$(pat_1, \,....\,, pat_n)$	Tuple patterns
	$[pat_1; \,..\,; pat_n \,;^?]$	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
	N	Nexp var, has type num
	fun $psexp$	Curried functions
	function $\|^?\ pexp_1 \| \,...\, \|pexp_n$ **end**	Functions with pattern matching
	$exp_1\ exp_2$	Function applications
	$exp_1\ ix^l\ exp_2$	Infix applications
	$\langle\|fexps\|\rangle$	Records
	$\langle\|exp$ **with** $fexps\|\rangle$	Functional update for records
	$exp.id$	Field projection for records
	$[\|exp_1; \,..\,; exp_n \,;^?\|]$	Vector instantiation
	$exp.(Nexp)$	Vector access
	$exp.(Nexp_1..Nexp_2)$	Subvector extraction
	match exp **with** $\|^?\ pexp_1 \| \,...\, \|pexp_n\ l$ **end**	Pattern matching expressions
	$(exp : typ)$	Type-annotated expressions
	let $letbind$ **in** exp	Let expressions
	$(exp_1, \,....\,, exp_n)$	Tuples
	$[exp_1; \,..\,; exp_n \,;^?]$	Lists
	(exp)	
	begin exp **end**	Alternate syntax for (exp)
	if exp_1 **then** exp_2 **else** exp_3	Conditionals
	$exp_1 :: exp_2$	Cons expressions
	lit	Literal constants
	$\{exp_1 \| exp_2\}$	Set comprehensions
	$\{exp_1 \|$ **forall** $qbind_1 \,..\, qbind_n \| exp_2\}$	Set comprehensions with explicit bin
	$\{exp_1; \,..\,; exp_n \,;^?\}$	Sets
	$q\ qbind_1 \,...\, qbind_n.exp$	Logical quantifications
	$[exp_1 |$ **forall** $qbind_1 \,..\, qbind_n \| exp_2]$	List comprehensions (all binders mus
	do $id\ pat_1 < -exp_1; \,..\, pat_n < -exp_n;$ **in** exp **end**	Do notation for monads

exp	::=		Location-annotated expressions
	|	*exp_aux l*	
q	::=		Quantifiers
	|	**forall**	
	|	**exists**	
qbind	::=		Bindings for quantifiers
	|	x^l	
	|	(*pat* **IN** *exp*)	Restricted quantifications over sets
	|	(*pat* **MEM** *exp*)	Restricted quantifications over lists
fexp	::=		Field-expressions
	|	*id* = *exp l*	
fexps	::=		Field-expression lists
	|	$fexp_1$; ... ; $fexp_n$ $;^?$ *l*	
pexp	::=		Pattern matches
	|	*pat* → *exp l*	
psexp	::=		Multi-pattern matches
	|	pat_1 ... pat_n → *exp l*	
$tannot^?$	::=		Optional type annotations
	|		
	|	: *typ*	
funcl_aux	::=		Function clauses
	|	x^l pat_1 ... pat_n $tannot^?$ = *exp*	
letbind_aux	::=		Let bindings
	|	*pat* $tannot^?$ = *exp*	Value bindings
	|	*funcl_aux*	Function bindings
letbind	::=		Location-annotated let bindings
	|	*letbind_aux l*	
funcl	::=		Location-annotated function clauses
	|	*funcl_aux l*	
name_t	::=		Name or name with type for inductively defined relatio
	|	x^l	
	|	(x^l : *typ*)	
name_ts	::=		Names with optional types for inductively defined relati
	|	$name\_t_0$ .. $name\_t_n$	

rule_aux	::=		Inductively defined relat
	|	x^l : **forall** $name\_t_1$ .. $name\_t_i.exp \Longrightarrow x_1^l\ exp_1$ .. exp_n	
rule	::=		Location-annotated indu
	|	$rule\_aux\ l$	
$witness^?$	::=		Optional witness type na
	|		
	|	**witness type** x^l;	
$check^?$	::=		Option check name decla
	|		
	|	**check** x^l;	
$functions^?$	::=		Optional names and typ
	|		
	|	$x^l : typ$	
	|	$x^l : typ; functions^?$	
indreln_name_aux	::=		Name for inductively de
	|	$[x^l : typschm\ witness^?\ check^?\ functions^?]$	
indreln_name	::=		Location-annotated nam
	|	$indreln\_name\_aux\ l$	
typs	::=		Type lists
	|	$typ_1 * ... * typ_n$	
ctor_def	::=		Datatype definition clau
	|	x^l **of** *typs*	
	|	x^l	S Constant constructors
texp	::=		Type definition bodies
	|	*typ*	Type abbreviations
	|	$\langle \vert x_1^l : typ_1; ... ; x_n^l : typ_n\ ;^? \vert \rangle$	Record types
	|	$\vert^?\ ctor\_def_1 \vert ... \vert ctor\_def_n$	Variant types
$name^?$	::=		Optional name specificat
	|		
	|	$[name = regexp]$	
td	::=		Type definitions
	|	$x^l\ tnvars^l\ name^? = texp$	
	|	$x^l\ tnvars^l\ name^?$	Definitions of opaque
c	::=		Typeclass constraints
	|	$id\ tnvar^l$	

cs	::=		Typeclass and length constraint l
	|		
	|	$c_1, .., c_i \Rightarrow$	Must have > 0 constraints
	|	$Nexp\_constraint_1, .., Nexp\_constraint_i \Rightarrow$	Must have > 0 constraints
	|	$c_1, .., c_i; Nexp\_constraint_1, .., Nexp\_constraint_n \Rightarrow$	Must have > 0 of both form of
c_pre	::=		Type and instance scheme prefixe
	|		
	|	**forall** $tnvar_1^l .. tnvar_n^l.cs$	Must have > 0 type variables
typschm	::=		Type schemes
	|	*c_pre typ*	
instschm	::=		Instance schemes
	|	$c\_pre(id\ typ)$	
target	::=		Backend target names
	|	**hol**	
	|	**isabelle**	
	|	**ocaml**	
	|	**coq**	
	|	**tex**	
	|	**html**	
τ	::=		Backend target name lists
	|	$\{target_1; ..; target_n\}$	
$\tau^?$	::=		Optional targets
	|		
	|	τ	
lemma_typ	::=		Types of Lemmata
	|	**assert**	
	|	**lemma**	
	|	**theorem**	
lemma_decl	::=		Lemmata and Tests
	|	$lemma\_typ\ \tau^?\ x^l : (exp)$	
	|	$lemma\_typ\ \tau^?(exp)$	
val_def	::=		Value definitions
	|	**let** $\tau^?$ *letbind*	Non-recursive value definitions
	|	**let rec** $\tau^?$ $funcl_1$ **and** ... **and** $funcl_n$	Recursive function definitions
	|	**let inline** $\tau^?$ *letbind*	Function definitions to be inlin
val_spec	::=		Value type specifications
	|	**val** x^l : *typschm*	

def_aux	::=			Top-level d
	|	**type** td_1 **and** ... **and** td_n		Type def
	|	*val_def*		Value de
	|	*lemma_decl*		Lemmata
	|	**rename** $\tau^?$ *id* $= x^l$		Rename
	|	**module** $x^l =$ **struct** *defs* **end**		Module
	|	**module** $x^l =$ *id*		Module
	|	**open** *id*		Opening
	|	**indreln** $\tau^?$ *indreln_name*$_1$ **and** ... **and** *indreln_name*$_i$ *rule*$_1$ **and** ... **and** *rule*$_n$		Inductive
	|	*val_spec*		Top-level
	|	**class** $(x^l\ tnvar^l)$ **val** x_1^l : *typ*$_1$ l_1 ... **val** x_n^l : *typ*$_n$ l_n **end**		Typeclas
	|	**instance** *instschm val_def*$_1$ l_1 ... *val_def*$_n$ l_n **end**		Typeclas
def	::=			Location-a
	|	*def_aux* l		
$;;^?$	::=			Optional d
	|			
	|	;;		
defs	::=			Definition s
	|	$def_1\ ;;_1^?\ ..\ def_n\ ;;_n^?$		
p	::=			Unique pat
	|	$x_1 ... x_n.x$		
	|	**__list**		
	|	**__bool**		
	|	**__num**		
	|	**__set**		
	|	**__string**		
	|	**__unit**		
	|	**__bit**		
	|	**__vector**		
σ	::=			Type varia
	|	$\{tnv_1 \mapsto t_1\ ..\ tnv_n \mapsto t_n\}$		
$t,\ u$	::=			Internal typ
	|	α		
	|	$t_1 \to t_2$		
	|	$t_1 * .... * t_n$		
	|	$p\ t\_args$		
	|	ne		
	|	$\sigma(t)$	M	Multiple
	|	$\sigma(tnv)$	M	Single va
	|	**curry** (t_multi, t)	M	Curried,

ne	::=			internal numeric expressions
	|	N		
	|	nat		
	|	$ne_1 * ne_2$		
	|	$ne_1 + ne_2$		
	|	$(-ne)$		
	|	**normalize** (ne)	M	
	|	$ne_1 + \ ... \ + ne_n$	M	
	|	**bitlength** (bin)	M	
	|	**bitlength** (hex)	M	
	|	**length** $(pat_1 \ ... \ pat_n)$	M	
	|	**length** $(exp_1 \ ... \ exp_n)$	M	
t_args	::=			Lists of types
	|	$t_1 \ .. \ t_n$		
	|	$\sigma(t\_args)$	M	Multiple substitutions
t_multi	::=			Lists of types
	|	$(t_1 * \ .. \ * t_n)$		
	|	$\sigma(t\_multi)$	M	Multiple substitutions
nec	::=			Numeric expression constraints
	|	$ne \langle nec$		
	|	$ne = nec$		
	|	$ne <= nec$		
	|	ne		
$names$	::=			Sets of names
	|	$\{x_1, \ .. \ , x_n\}$		
$\mathcal{C}$	::=			Typeclass constraint lists
	|	$(p_1 \ tnv_1) \ .. \ (p_n \ tnv_n)$		
env_tag	::=			Tags for the (non-constructor) value descripti
	|	**method**		Bound to a method
	|	**val**		Specified with val
	|	**let**		Defined with let or indreln
v_desc	::=			Value descriptions
	|	$\langle$ **forall** $tnvs.t\_multi \rightarrow p, (x$ **of** $names)\rangle$		Constructors
	|	$\langle$ **forall** $tnvs.\mathcal{C} \Rightarrow t, env\_tag\rangle$		Values
f_desc	::=			
	|	$\langle$ **forall** $tnvs.p \rightarrow t, (x$ **of** $names)\rangle$		Fields
xs	::=			
	|	$x_1 \ .. \ x_n$		

$\Sigma^{\mathcal{C}}$	::=		Typeclass constraints
	$\mid$	$\{(p_1\ t_1),\ ..,(p_n\ t_n)\}$	
	$\mid$	${\Sigma^{\mathcal{C}}}_1 \cup .. \cup {\Sigma^{\mathcal{C}}}_n$	M
$\Sigma^{\mathcal{N}}$	::=		Nexp constraint lists
	$\mid$	$\{nec_1,\ ..,nec_n\}$	
	$\mid$	${\Sigma^{\mathcal{N}}}_1 \cup .. \cup {\Sigma^{\mathcal{N}}}_n$	M
E	::=		Environments
	$\mid$	$\langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}}\rangle$	
	$\mid$	$E_1 \uplus E_2$	M
	$\mid$	ϵ	M
E^{X}	::=		Value environments
	$\mid$	$\{x_1 \mapsto v\_desc_1,\ ..,x_n \mapsto v\_desc_n\}$	
	$\mid$	$E_1^{\mathrm{X}} \uplus .. \uplus E_n^{\mathrm{X}}$	M
E^{F}	::=		Field environments
	$\mid$	$\{x_1 \mapsto f\_desc_1,\ ..,x_n \mapsto f\_desc_n\}$	
	$\mid$	$E_1^{\mathrm{F}} \uplus .. \uplus E_n^{\mathrm{F}}$	M
E^{M}	::=		Module environments
	$\mid$	$\{x_1 \mapsto E_1,\ ..,x_n \mapsto E_n\}$	
E^{P}	::=		Path environments
	$\mid$	$\{x_1 \mapsto p_1,\ ..,x_n \mapsto p_n\}$	
	$\mid$	$E_1^{\mathrm{P}} \uplus .. \uplus E_n^{\mathrm{P}}$	M
E^{L}	::=		Lexical bindings
	$\mid$	$\{x_1 \mapsto t_1,\ ..,x_n \mapsto t_n\}$	
	$\mid$	$\{x_1^l \mapsto t_1,\ ..,x_n^l \mapsto t_n\}$	
	$\mid$	$E_1^{\mathrm{L}} \uplus .. \uplus E_n^{\mathrm{L}}$	M
tc_abbrev	::=		Type abbreviations
	$\mid$	$.t$	
	$\mid$		
tc_def	::=		Type and class constructor definitions
	$\mid$	$tnvs\ tc\_abbrev$	Type constructors
Δ	::=		Type constructor definitions
	$\mid$	$\{p_1 \mapsto tc\_def_1,\ ..,p_n \mapsto tc\_def_n\}$	
	$\mid$	$\Delta_1 \uplus \Delta_2$	M
δ	::=		Typeclass definitions
	$\mid$	$\{p_1 \mapsto xs_1,\ ..,p_n \mapsto xs_n\}$	
	$\mid$	$\delta_1 \uplus \delta_2$	M

inst	::=			A typeclass instance, t must not contain nested types
	|	$\mathcal{C} \Rightarrow (p\ t)$		
I	::=			Global instances
	|	$\{inst_1, .., inst_n\}$		
	|	$I_1 \cup I_2$	M	
D	::=			Global type definition store
	|	$\langle \Delta, \delta, I \rangle$		
	|	$D_1 \uplus D_2$	M	
	|	ϵ	M	
terminals	::=			
	|	$\geq$		>=
	|	$\rightarrow$		->
	|	$\Longrightarrow$		==>
	|	$\langle\vert$		<|
	|	$\vert\rangle$		|>
	|	$\cap$		
	|	$\cup$		
	|	$\uplus$		
	|	$\notin$		
	|	$\subset$		
	|	$\neq$		
	|	$\emptyset$		
	|	$\langle$		
	|	$\rangle$		
	|	$\vdash$		
	|	,		
	|	$\mapsto$		
	|	$\triangleright$		
	|	$\rightsquigarrow$		
	|	$\Rightarrow$		
	|	$\_$		
	|	ϵ		
formula	::=			
	|	*judgement*		
	|	$formula_1 \quad .. \quad formula_n$		
	|	$E^{\mathrm{M}}(x) \triangleright E$		Module lookup
	|	$E^{\mathrm{P}}(x) \triangleright p$		Path lookup
	|	$E^{\mathrm{F}}(x) \triangleright f\_desc$		Field lookup
	|	$E^{\mathrm{X}}(x) \triangleright v\_desc$		Value lookup
	|	$E^{\mathrm{L}}(x) \triangleright t$		Lexical binding lookup
	|	$\Delta(p) \triangleright tc\_def$		Type constructor lookup
	|	$\delta(p) \triangleright xs$		Type constructor lookup
	|	$\mathbf{dom}\,(E_1^{\mathrm{M}}) \cap \mathbf{dom}\,(E_2^{\mathrm{M}}) = \emptyset$		

	$\mathbf{dom}\,(E_1^{\mathrm{X}}) \cap \mathbf{dom}\,(E_2^{\mathrm{X}}) = \emptyset$	
	$\mathbf{dom}\,(E_1^{\mathrm{F}}) \cap \mathbf{dom}\,(E_2^{\mathrm{F}}) = \emptyset$	
	$\mathbf{dom}\,(E_1^{\mathrm{P}}) \cap \mathbf{dom}\,(E_2^{\mathrm{P}}) = \emptyset$	
	$\mathbf{disjoint\,doms}\,(E_1^{\mathrm{L}}, \ldots., E_n^{\mathrm{L}})$	Pairwise disjoint domains
	$\mathbf{disjoint\,doms}\,(E_1^{\mathrm{X}}, \ldots., E_n^{\mathrm{X}})$	Pairwise disjoint domains
	$\mathbf{compatible\,overlap}\,(x_1 \mapsto t_1, .., x_n \mapsto t_n)$	$(x_i = x_j) \Longrightarrow (t_i = t_j)$
	$\mathbf{duplicates}\,(tnvs) = \emptyset$	
	$\mathbf{duplicates}\,(x_1, .., x_n) = \emptyset$	
	$x \notin \mathbf{dom}\,(E^{\mathrm{L}})$	
	$x \notin \mathbf{dom}\,(E^{\mathrm{X}})$	
	$x \notin \mathbf{dom}\,(E^{\mathrm{F}})$	
	$p \notin \mathbf{dom}\,(\delta)$	
	$p \notin \mathbf{dom}\,(\Delta)$	
	$\mathbf{FV}\,(t) \subset tnvs$	Free type variables
	$\mathbf{FV}\,(t\_multi) \subset tnvs$	Free type variables
	$\mathbf{FV}\,(\mathcal{C}) \subset tnvs$	Free type variables
	$inst\,\mathbf{IN}\,I$	
	$(p\ t) \notin I$	
	$E_1^{\mathrm{L}} = E_2^{\mathrm{L}}$	
	$E_1^{\mathrm{X}} = E_2^{\mathrm{X}}$	
	$E_1^{\mathrm{F}} = E_2^{\mathrm{F}}$	
	$E_1 = E_2$	
	$\Delta_1 = \Delta_2$	
	$\delta_1 = \delta_2$	
	$I_1 = I_2$	
	$names_1 = names_2$	
	$t_1 = t_2$	
	$\sigma_1 = \sigma_2$	
	$p_1 = p_2$	
	$xs_1 = xs_2$	
	$tnvs_1 = tnvs_2$	

convert_tnvars	::=		
	|	$tnvars^l \rightsquigarrow tnvs$	
	|	$tnvar^l \rightsquigarrow tnv$	
look_m	::=		
	|	$E_1(x_1^l \,..\, x_n^l) \triangleright E_2$	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

	$\Delta, tnv \vdash t$ **ok**	Well-formed type/Nexps ma
teq	::=	
	$\Delta \vdash t_1 = t_2$	Type equality
convert_typ	::=	
	$\Delta, E \vdash typ \rightsquigarrow t$	Convert source types to int
	$\vdash Nexp \rightsquigarrow ne$	Convert and normalize num
convert_typs	::=	
	$\Delta, E \vdash typs \rightsquigarrow t\_multi$	
check_lit	::=	
	$\vdash lit : t$	Typing literal constants
inst_field	::=	
	$\Delta, E \vdash$ **field** $id : p\ t\_args \to t \triangleright (x$ **of** $names)$	Field typing (also returns c
inst_ctor	::=	
	$\Delta, E \vdash$ **ctor** $id : t\_multi \to p\ t\_args \triangleright (x$ **of** $names)$	Data constructor typing (al
inst_val	::=	
	$\Delta, E \vdash$ **val** $id : t \triangleright \Sigma^{\mathcal{C}}$	Typing top-level bindings,
not_ctor	::=	
	$E, E^{\mathrm{L}} \vdash x$ **not ctor**	v is not bound to a data co
not_shadowed	::=	
	$E^{\mathrm{L}} \vdash id$ **not shadowed**	id is not lexically shadowed
check_pat	::=	
	$\Delta, E, E_1^{\mathrm{L}} \vdash pat : t \triangleright E_2^{\mathrm{L}}$	Typing patterns, building t
	$\Delta, E, E_1^{\mathrm{L}} \vdash pat\_aux : t \triangleright E_2^{\mathrm{L}}$	Typing patterns, building t
id_field	::=	
	$E \vdash id$ **field**	Check that the identifier is
id_value	::=	
	$E \vdash id$ **value**	Check that the identifier is
check_exp	::=	
	$\Delta, E, E^{\mathrm{L}} \vdash exp : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}$	Typing expressions, collecti
	$\Delta, E, E^{\mathrm{L}} \vdash exp\_aux : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}$	Typing expressions, collecti
	$\Delta, E, E_1^{\mathrm{L}} \vdash qbind_1\ ..\ qbind_n \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}$	Build the environment for q
	$\Delta, E, E_1^{\mathrm{L}} \vdash$ **list** $qbind_1\ ..\ qbind_n \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}$	Build the environment for q
	$\Delta, E, E^{\mathrm{L}} \vdash funcl \triangleright \{x \mapsto t\}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}$	Build the environment for a
	$\Delta, E, E_1^{\mathrm{L}} \vdash letbind \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}$	Build the environment for a

check_rule	::=		
	|	$\Delta, E, E^{\mathrm{L}} \vdash \mathit{rule} \triangleright \{x \mapsto t\}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}$	Build the environment for an induc
check_texp_tc	::=		
	|	$\mathit{xs}, \Delta_1, E \vdash \mathbf{tc}\, \mathit{td} \triangleright \Delta_2, E^{\mathrm{P}}$	Extract the type constructor inform
check_texps_tc	::=		
	|	$\mathit{xs}, \Delta_1, E \vdash \mathbf{tc}\, \mathit{td}_1 .. \mathit{td}_i \triangleright \Delta_2, E^{\mathrm{P}}$	Extract the type constructor inform
check_texp	::=		
	|	$\Delta, E \vdash \mathit{tnvs}\ p = \mathit{texp} \triangleright \langle E^{\mathrm{F}}, E^{\mathrm{X}} \rangle$	Check a type definition, with its pa
check_texps	::=		
	|	$\mathit{xs}, \Delta, E \vdash \mathit{td}_1 .. \mathit{td}_n \triangleright \langle E^{\mathrm{F}}, E^{\mathrm{X}} \rangle$	
convert_class	::=		
	|	$\delta, E \vdash \mathit{id} \rightsquigarrow p$	Lookup a type class
solve_class_constraint	::=		
	|	$I \vdash (p\ t)\, \mathbf{IN}\, \mathcal{C}$	Solve class constraint
solve_class_constraints	::=		
	|	$I \vdash \Sigma^{\mathcal{C}} \triangleright \mathcal{C}$	Solve class constraints
check_val_def	::=		
	|	$\Delta, I, E \vdash \mathit{val\_def} \triangleright E^{\mathrm{X}}$	Check a value definition
check_t_instance	::=		
	|	$\Delta, (\alpha_1, .., \alpha_n) \vdash t\, \mathbf{instance}$	Check that t be a typeclass instanc
check_defs	::=		
	|	$\overline{z_j}^{\,j}, D_1, E_1 \vdash \mathit{def} \triangleright D_2, E_2$	Check a definition
	|	$\overline{z_j}^{\,j}, D_1, E_1 \vdash \mathit{defs} \triangleright D_2, E_2$	Check definitions, given module pa
judgement	::=		
	|	*convert_tnvars*	
	|	*look_m*	
	|	*look_m_id*	
	|	*look_tc*	
	|	*check_t*	
	|	*teq*	
	|	*convert_typ*	
	|	*convert_typs*	
	|	*check_lit*	
	|	*inst_field*	
	|	*inst_ctor*	
	|	*inst_val*	

| *not_ctor*
| *not_shadowed*
| *check_pat*
| *id_field*
| *id_value*
| *check_exp*
| *check_rule*
| *check_texp_tc*
| *check_texps_tc*
| *check_texp*
| *check_texps*
| *convert_class*
| *solve_class_constraint*
| *solve_class_constraints*
| *check_val_def*
| *check_t_instance*
| *check_defs*

user_syntax ::=
| n
| *num*
| *nat*
| *hex*
| *bin*
| *string*
| *regexp*
| x
| *ix*
| l
| x^l
| ix^l
| α
| α^l
| N
| N^l
| *id*
| *tnv*
| $tnvar^l$
| *tnvs*
| $tnvars^l$
| *Nexp_aux*
| *Nexp*
| *Nexp_constraint_aux*
| *Nexp_constraint*
| *typ_aux*
| *typ*

| *lit_aux*
| *lit*
| ;?
| *pat_aux*
| *pat*
| *fpat*
| |?
| *exp_aux*
| *exp*
| *q*
| *qbind*
| *fexp*
| *fexps*
| *pexp*
| *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*
| τ
| τ?
| *lemma_typ*
| *lemma_decl*
| *val_def*
| *val_spec*

| def_aux
| def
| $;;^{?}$
| $defs$
| p
| σ
| 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^{X}
| E^{F}
| E^{M}
| E^{P}
| E^{L}
| tc_abbrev
| tc_def
| Δ
| δ
| $inst$
| I
| D
| $terminals$
| $formula$

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

$$\frac{tnvar_1^{l} \rightsquigarrow tnv_1 \quad .. \quad tnvar_n^{l} \rightsquigarrow tnv_n}{tnvar_1^{l} \,..\, tnvar_n^{l} \rightsquigarrow tnv_1 \,..\, tnv_n}\ \text{CONVERT\_TNVARS\_NONE}$$

$\boxed{tnvar^{l} \rightsquigarrow tnv}$

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

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

$\boxed{E_1(x_1^{l} \,..\, x_n^{l}) \triangleright E_2}$ Name path lookup

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

$$\frac{E^{\mathrm{M}}(x) \triangleright E_1 \quad E_1(\overline{y_i^l}^{\,i}) \triangleright E_2}{\langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}}\rangle (x\ l\ \overline{y_i^l}^{\,i}) \triangleright E_2}\ \textsc{look\_m\_some}$$

$\boxed{E_1(id) \triangleright E_2}$ Module identifier lookup

$$\frac{E_1(\overline{y_i^l}^{\,i}\ x\ l_1) \triangleright E_2}{E_1(\overline{y_i^l.}^{\,i}\ x\ l_1\ l_2) \triangleright E_2}\ \textsc{look\_m\_id\_all}$$

$\boxed{E(id) \triangleright p}$ Path identifier lookup

$$\frac{E(\overline{y_i^l}^{\,i}) \triangleright \langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}}\rangle \quad E^{\mathrm{P}}(x) \triangleright p}{E(\overline{y_i^l.}^{\,i}\ x\ l_1\ l_2) \triangleright p}\ \textsc{look\_tc\_all}$$

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

$$\frac{}{\Delta \vdash \alpha\ \mathbf{ok}}\ \textsc{check\_t\_var}$$

$$\frac{\Delta \vdash t_1\ \mathbf{ok} \quad \Delta \vdash t_2\ \mathbf{ok}}{\Delta \vdash t_1 \to t_2\ \mathbf{ok}}\ \textsc{check\_t\_fn}$$

$$\frac{\Delta \vdash t_1\ \mathbf{ok} \quad .... \quad \Delta \vdash t_n\ \mathbf{ok}}{\Delta \vdash t_1 * .... * t_n\ \mathbf{ok}}\ \textsc{check\_t\_tup}$$

$$\frac{\Delta(p) \triangleright tnv_1 .. tnv_n\ tc\_abbrev \quad \Delta, tnv_1 \vdash t_1\ \mathbf{ok} \quad .. \quad \Delta, tnv_n \vdash t_n\ \mathbf{ok}}{\Delta \vdash p\ t_1 .. t_n\ \mathbf{ok}}\ \textsc{check\_t\_app}$$

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

$$\frac{\Delta \vdash t\ \mathbf{ok}}{\Delta, \alpha \vdash t\ \mathbf{ok}}\ \textsc{check\_tlen\_t}$$

$$\frac{}{\Delta, N \vdash ne\ \mathbf{ok}}\ \textsc{check\_tlen\_len}$$

$\boxed{\Delta \vdash t_1 = t_2}$ Type equality

$$\frac{\Delta \vdash t\ \mathbf{ok}}{\Delta \vdash t = t}\ \textsc{teq\_refl}$$

$$\frac{\Delta \vdash t_2 = t_1}{\Delta \vdash t_1 = t_2}\ \textsc{teq\_sym}$$

$$\frac{\Delta \vdash t_1 = t_2 \quad \Delta \vdash t_2 = t_3}{\Delta \vdash t_1 = t_3}\ \textsc{teq\_trans}$$

$$\frac{\Delta \vdash t_1 = t_3 \quad \Delta \vdash t_2 = t_4}{\Delta \vdash t_1 \to t_2 = t_3 \to t_4}\ \textsc{teq\_arrow}$$

$$\frac{\Delta \vdash t_1 = u_1 \quad .... \quad \Delta \vdash t_n = u_n}{\Delta \vdash t_1 * .... * t_n = u_1 * .... * u_n}\ \textsc{teq\_tup}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\frac{}{\vdash \mathbf{true}\, l : \_\_\mathbf{bool}} \quad \text{CHECK\_LIT\_TRUE}$$

$$\frac{}{\vdash \mathbf{false}\, l : \_\_\mathbf{bool}} \quad \text{CHECK\_LIT\_FALSE}$$

$$\frac{}{\vdash num\, l : \_\_\mathbf{num}} \quad \text{CHECK\_LIT\_NUM}$$

$$\frac{nat = \mathbf{bitlength}\,(hex)}{\vdash hex\, l : \_\_\mathbf{vector}\, nat\, \_\_\mathbf{bit}} \quad \text{CHECK\_LIT\_HEX}$$

$$\frac{nat = \mathbf{bitlength}\,(bin)}{\vdash bin\, l : \_\_\mathbf{vector}\, nat\, \_\_\mathbf{bit}} \quad \text{CHECK\_LIT\_BIN}$$

$$\frac{}{\vdash string\, l : \_\_\mathbf{string}} \quad \text{CHECK\_LIT\_STRING}$$

$$\frac{}{\vdash ()\, l : \_\_\mathbf{unit}} \quad \text{CHECK\_LIT\_UNIT}$$

$$\frac{}{\vdash \mathbf{bitzero}\, l : \_\_\mathbf{bit}} \quad \text{CHECK\_LIT\_BITZERO}$$

$$\frac{}{\vdash \mathbf{bitone}\, l : \_\_\mathbf{bit}} \quad \text{CHECK\_LIT\_BITONE}$$

$\boxed{\Delta, E \vdash \mathbf{field}\, id : p\, t\_args \to t \triangleright (x\, \mathbf{of}\, names)}$ Field typing (also returns canonical field names)

$$\frac{\begin{array}{l} E(\overline{x_i^l}^{\,i}) \triangleright \langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}} \rangle \\ E^{\mathrm{F}}(y) \triangleright \langle \mathbf{forall}\, tnv_1 .. tnv_n . p \to t, (z\, \mathbf{of}\, names) \rangle \\ \Delta \vdash t_1\, \mathbf{ok} \quad .. \quad \Delta \vdash t_n\, \mathbf{ok} \end{array}}{\Delta, E \vdash \mathbf{field}\, \overline{x_i^l}^{\,i}\, y\, l_1\, l_2 : p\, t_1 .. t_n \to \{tnv_1 \mapsto t_1 .. tnv_n \mapsto t_n\}(t) \triangleright (z\, \mathbf{of}\, names)} \quad \text{INST\_FIELD\_ALL}$$

$\boxed{\Delta, E \vdash \mathbf{ctor}\, id : t\_multi \to p\, t\_args \triangleright (x\, \mathbf{of}\, names)}$ Data constructor typing (also returns canonical constru

$$\frac{\begin{array}{l} E(\overline{x_i^l}^{\,i}) \triangleright \langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}} \rangle \\ E^{\mathrm{X}}(y) \triangleright \langle \mathbf{forall}\, tnv_1 .. tnv_n . t\_multi \to p, (z\, \mathbf{of}\, names) \rangle \\ \Delta \vdash t_1\, \mathbf{ok} \quad .. \quad \Delta \vdash t_n\, \mathbf{ok} \end{array}}{\Delta, E \vdash \mathbf{ctor}\, \overline{x_i^l}^{\,i}\, y\, l_1\, l_2 : \{tnv_1 \mapsto t_1 .. tnv_n \mapsto t_n\}(t\_multi) \to p\, t_1 .. t_n \triangleright (z\, \mathbf{of}\, names)} \quad \text{INST\_CTOR\_ALL}$$

$\boxed{\Delta, E \vdash \mathbf{val}\, id : t \triangleright \Sigma^{\mathcal{C}}}$ Typing top-level bindings, collecting typeclass constraints

$$\frac{\begin{array}{l} E(\overline{x_i^l}^{\,i}) \triangleright \langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}} \rangle \\ E^{\mathrm{X}}(y) \triangleright \langle \mathbf{forall}\, tnv_1 .. tnv_n . (p_1\, tnv_1') .. (p_i\, tnv_i') \Rightarrow t, env\_tag \rangle \\ \Delta \vdash t_1\, \mathbf{ok} \quad .. \quad \Delta \vdash t_n\, \mathbf{ok} \\ \sigma = \{tnv_1 \mapsto t_1 .. tnv_n \mapsto t_n\} \end{array}}{\Delta, E \vdash \mathbf{val}\, \overline{x_i^l}^{\,i}\, y\, l_1\, l_2 : \sigma(t) \triangleright \{(p_1\, \sigma(tnv_1')), .., (p_i\, \sigma(tnv_i'))\}} \quad \text{INST\_VAL\_ALL}$$

$\boxed{E, E^{\mathrm{L}} \vdash x\, \mathbf{not\, ctor}}$ v is not bound to a data constructor

$$\frac{E^{\mathrm{L}}(x) \triangleright t}{E, E^{\mathrm{L}} \vdash x\, \mathbf{not\, ctor}} \quad \text{NOT\_CTOR\_VAL}$$

$$\frac{x \notin \mathbf{dom}\,(E^{\mathrm{X}})}{\langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}} \rangle, E^{\mathrm{L}} \vdash x\, \mathbf{not\, ctor}} \quad \text{NOT\_CTOR\_UNBOUND}$$

$$\frac{E^{\mathrm{X}}(x) \triangleright \langle \mathbf{forall}\, tnv_1 .. tnv_n . (p_1\, tnv_1') .. (p_i\, tnv_i') \Rightarrow t, env\_tag \rangle}{\langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}} \rangle, E^{\mathrm{L}} \vdash x\, \mathbf{not\, ctor}} \quad \text{NOT\_CTOR\_BOUND}$$

$\boxed{E^{\mathrm{L}} \vdash id\ \mathbf{not\ shadowed}}$ id is not lexically shadowed

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

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

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

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

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

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

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

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

$$\frac{\begin{array}{l}\Delta, E \vdash \mathbf{ctor}\ id : (t_1 * .. * t_n) \to p\ t\_args \triangleright (x\ \mathbf{of}\ names) \\ E^{\mathrm{L}} \vdash id\ \mathbf{not\ shadowed} \\ \Delta, E, E^{\mathrm{L}} \vdash pat_1 : t_1 \triangleright E_1^{\mathrm{L}} \quad .. \quad \Delta, E, E^{\mathrm{L}} \vdash pat_n : t_n \triangleright E_n^{\mathrm{L}} \\ \mathbf{disjoint\ doms}\,(E_1^{\mathrm{L}}, .., E_n^{\mathrm{L}})\end{array}}{\Delta, E, E^{\mathrm{L}} \vdash id\ pat_1 .. pat_n : p\ t\_args \triangleright E_1^{\mathrm{L}} \uplus .. \uplus E_n^{\mathrm{L}}}\ \text{CHECK\_PAT\_AUX\_IDENT\_CONSTR}$$

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

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

$$\frac{\begin{array}{l}\Delta, E, E^{\mathrm{L}} \vdash pat_1 : t \triangleright E_1^{\mathrm{L}} \quad ... \quad \Delta, E, E^{\mathrm{L}} \vdash pat_n : t \triangleright E_n^{\mathrm{L}} \\ \mathbf{disjoint\ doms}\,(E_1^{\mathrm{L}}, ..., E_n^{\mathrm{L}}) \\ \mathbf{length}\,(pat_1 ... pat_n) = nat\end{array}}{\Delta, E, E^{\mathrm{L}} \vdash [|pat_1; ...; pat_n\,;^?|] : \_\_\mathbf{vector}\ nat\ t \triangleright E_1^{\mathrm{L}} \uplus ... \uplus E_n^{\mathrm{L}}}\ \text{CHECK\_PAT\_AUX\_VECTOR}$$

$$\frac{\begin{array}{l}\Delta, E, E^{\mathrm{L}} \vdash pat_1 : \_\_\mathbf{vector}\ ne_1\ t \triangleright E_1^{\mathrm{L}} \quad ... \quad \Delta, E, E^{\mathrm{L}} \vdash pat_n : \_\_\mathbf{vector}\ ne_n\ t \triangleright E_n^{\mathrm{L}} \\ \mathbf{disjoint\ doms}\,(E_1^{\mathrm{L}}, ..., E_n^{\mathrm{L}}) \\ ne' = ne_1 + ... + ne_n\end{array}}{\Delta, E, E^{\mathrm{L}} \vdash [|pat_1 ... pat_n|] : \_\_\mathbf{vector}\ ne'\ t \triangleright E_1^{\mathrm{L}} \uplus ... \uplus E_n^{\mathrm{L}}}\ \text{CHECK\_PAT\_AUX\_VECTOR}$$

$$\frac{\begin{array}{l}\Delta, E, E^{\mathrm{L}} \vdash pat_1 : t_1 \triangleright E_1^{\mathrm{L}} \quad .... \quad \Delta, E, E^{\mathrm{L}} \vdash pat_n : t_n \triangleright E_n^{\mathrm{L}} \\ \mathbf{disjoint\ doms}\,(E_1^{\mathrm{L}}, ..., E_n^{\mathrm{L}})\end{array}}{\Delta, E, E^{\mathrm{L}} \vdash (pat_1, ..., pat_n) : t_1 * .... * t_n \triangleright E_1^{\mathrm{L}} \uplus .... \uplus E_n^{\mathrm{L}}}\ \text{CHECK\_PAT\_AUX\_TUP}$$

$$\frac{\begin{array}{l}\Delta \vdash t\ \mathbf{ok} \\ \Delta, E, E^{\mathrm{L}} \vdash pat_1 : t \triangleright E_1^{\mathrm{L}} \quad .. \quad \Delta, E, E^{\mathrm{L}} \vdash pat_n : t \triangleright E_n^{\mathrm{L}} \\ \mathbf{disjoint\ doms}\,(E_1^{\mathrm{L}}, .., E_n^{\mathrm{L}})\end{array}}{\Delta, E, E^{\mathrm{L}} \vdash [pat_1; ..; pat_n ;^{?}] : \_\_\mathbf{list}\ t \triangleright E_1^{\mathrm{L}} \uplus .. \uplus E_n^{\mathrm{L}}}\ \textsc{check\_pat\_aux\_list}$$

$$\frac{\Delta, E, E_1^{\mathrm{L}} \vdash pat : t \triangleright E_2^{\mathrm{L}}}{\Delta, E, E_1^{\mathrm{L}} \vdash (pat) : t \triangleright E_2^{\mathrm{L}}}\ \textsc{check\_pat\_aux\_paren}$$

$$\frac{\begin{array}{l}\Delta, E, E_1^{\mathrm{L}} \vdash pat_1 : t \triangleright E_2^{\mathrm{L}} \\ \Delta, E, E_1^{\mathrm{L}} \vdash pat_2 : \_\_\mathbf{list}\ t \triangleright E_3^{\mathrm{L}} \\ \mathbf{disjoint\ doms}\,(E_2^{\mathrm{L}}, E_3^{\mathrm{L}})\end{array}}{\Delta, E, E_1^{\mathrm{L}} \vdash pat_1 :: pat_2 : \_\_\mathbf{list}\ t \triangleright E_2^{\mathrm{L}} \uplus E_3^{\mathrm{L}}}\ \textsc{check\_pat\_aux\_cons}$$

$$\frac{\vdash lit : t}{\Delta, E, E^{\mathrm{L}} \vdash lit : t \triangleright \{\,\}}\ \textsc{check\_pat\_aux\_lit}$$

$$\frac{E, E^{\mathrm{L}} \vdash x\ \mathbf{not\ ctor}}{\Delta, E, E^{\mathrm{L}} \vdash x\ l + num : \_\_\mathbf{num}\ \triangleright \{x \mapsto \_\_\mathbf{num}\ \}}\ \textsc{check\_pat\_aux\_num\_add}$$

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

$$\frac{E^{\mathrm{F}}(x) \triangleright f\_desc}{\langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}} \rangle \vdash x\ l_1\ l_2\ \mathbf{field}}\ \textsc{id\_field\_empty}$$

$$\frac{\begin{array}{l}E^{\mathrm{M}}(x) \triangleright E \\ x \notin \mathbf{dom}\,(E^{\mathrm{F}}) \\ E \vdash \overline{y_i^l.}^{\,i}\ z^l\ l_2\ \mathbf{field}\end{array}}{\langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}} \rangle \vdash x\ l_1.\ \overline{y_i^l.}^{\,i}\ z^l\ l_2\ \mathbf{field}}\ \textsc{id\_field\_cons}$$

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

$$\frac{E^{\mathrm{X}}(x) \triangleright v\_desc}{\langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}} \rangle \vdash x\ l_1\ l_2\ \mathbf{value}}\ \textsc{id\_value\_empty}$$

$$\frac{\begin{array}{l}E^{\mathrm{M}}(x) \triangleright E \\ x \notin \mathbf{dom}\,(E^{\mathrm{X}}) \\ E \vdash \overline{y_i^l.}^{\,i}\ z^l\ l_2\ \mathbf{value}\end{array}}{\langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}} \rangle \vdash x\ l_1.\ \overline{y_i^l.}^{\,i}\ z^l\ l_2\ \mathbf{value}}\ \textsc{id\_value\_cons}$$

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

$$\frac{\Delta, E, E^{\mathrm{L}} \vdash exp\_aux : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}{\Delta, E, E^{\mathrm{L}} \vdash exp\_aux\ l : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}\ \textsc{check\_exp\_all}$$

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

$$\frac{E^{\mathrm{L}}(x) \triangleright t}{\Delta, E, E^{\mathrm{L}} \vdash x\ l_1\ l_2 : t \triangleright \{\,\}, \{\,\}}\ \textsc{check\_exp\_aux\_var}$$

$$\frac{}{\Delta, E, E^{\mathrm{L}} \vdash N : \_\_\mathbf{num}\ \triangleright \{\,\}, \{\,\}}\ \textsc{check\_exp\_aux\_nvar}$$

$$\frac{\begin{array}{l}E^{\mathrm{L}} \vdash id\ \mathbf{not\ shadowed} \\ E \vdash id\ \mathbf{value} \\ \Delta, E \vdash\ \mathbf{ctor}\ id : t\_multi \to p\ t\_args \triangleright (x\ \mathbf{of}\ names)\end{array}}{\Delta, E, E^{\mathrm{L}} \vdash id : \mathbf{curry}\,(t\_multi, p\ t\_args) \triangleright \{\,\}, \{\,\}}\ \textsc{check\_exp\_aux\_ctor}$$

$$\frac{\begin{array}{l} E^{\mathrm{L}} \vdash id \ \textbf{not shadowed} \\ E \vdash id \ \textbf{value} \\ \Delta, E \vdash \ \textbf{val}\ id : t \triangleright \Sigma^{\mathcal{C}} \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash id : t \triangleright \Sigma^{\mathcal{C}}, \{\,\}} \ \text{CHECK\_EXP\_AUX\_VAL}$$

$$\frac{\begin{array}{l} \Delta, E, E^{\mathrm{L}} \vdash pat_1 : t_1 \triangleright E_1^{\mathrm{L}} \quad ... \quad \Delta, E, E^{\mathrm{L}} \vdash pat_n : t_n \triangleright E_n^{\mathrm{L}} \\ \Delta, E, E^{\mathrm{L}} \uplus E_1^{\mathrm{L}} \uplus \ ... \ \uplus E_n^{\mathrm{L}} \vdash exp : u \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}} \\ \textbf{disjoint doms}\,(E_1^{\mathrm{L}}, \ ..., E_n^{\mathrm{L}}) \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash \textbf{fun}\ pat_1 \ ... \ pat_n \rightarrow exp\ l : \textbf{curry}\,((t_1 * \ ... \ * t_n), u) \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}} \ \text{CHECK\_EXP\_AUX\_FN}$$

$$\frac{\begin{array}{l} \overline{\Delta, E, E^{\mathrm{L}} \vdash pat_i : t \triangleright E_i^{\mathrm{L}}}^{\,i} \\ \overline{\Delta, E, E^{\mathrm{L}} \uplus E_i^{\mathrm{L}} \vdash exp_i : u \triangleright \Sigma^{\mathcal{C}}{}_i, \Sigma^{\mathcal{N}}{}_i}^{\,i} \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash \textbf{function}\ |^?\ \overline{pat_i \rightarrow exp_i\ l_i}^{\,i}\ \textbf{end} : t \rightarrow u \triangleright \overline{\Sigma^{\mathcal{C}}{}_i}^{\,i}, \overline{\Sigma^{\mathcal{N}}{}_i}^{\,i}} \ \text{CHECK\_EXP\_AUX\_FUNCTION}$$

$$\frac{\begin{array}{l} \Delta, E, E^{\mathrm{L}} \vdash exp_1 : t_1 \rightarrow t_2 \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \\ \Delta, E, E^{\mathrm{L}} \vdash exp_2 : t_1 \triangleright \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2 \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash exp_1\ exp_2 : t_2 \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_1 \cup \Sigma^{\mathcal{N}}{}_2} \ \text{CHECK\_EXP\_AUX\_APP}$$

$$\frac{\begin{array}{l} \Delta, E, E^{\mathrm{L}} \vdash \ (ix) \ : t_1 \rightarrow t_2 \rightarrow t_3 \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \\ \Delta, E, E^{\mathrm{L}} \vdash exp_1 : t_1 \triangleright \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2 \\ \Delta, E, E^{\mathrm{L}} \vdash exp_2 : t_2 \triangleright \Sigma^{\mathcal{C}}{}_3, \Sigma^{\mathcal{N}}{}_3 \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash exp_1\ ix\ l\ exp_2 : t_3 \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2 \cup \Sigma^{\mathcal{C}}{}_3, \Sigma^{\mathcal{N}}{}_1 \cup \Sigma^{\mathcal{N}}{}_2 \cup \Sigma^{\mathcal{N}}{}_3} \ \text{CHECK\_EXP\_AUX\_INFIX\_APP1}$$

$$\frac{\begin{array}{l} \Delta, E, E^{\mathrm{L}} \vdash \ x \ \ : t_1 \rightarrow t_2 \rightarrow t_3 \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \\ \Delta, E, E^{\mathrm{L}} \vdash exp_1 : t_1 \triangleright \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2 \\ \Delta, E, E^{\mathrm{L}} \vdash exp_2 : t_2 \triangleright \Sigma^{\mathcal{C}}{}_3, \Sigma^{\mathcal{N}}{}_3 \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash exp_1\ `x`l\ exp_2 : t_3 \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2 \cup \Sigma^{\mathcal{C}}{}_3, \Sigma^{\mathcal{N}}{}_1 \cup \Sigma^{\mathcal{N}}{}_2 \cup \Sigma^{\mathcal{N}}{}_3} \ \text{CHECK\_EXP\_AUX\_INFIX\_APP2}$$

$$\frac{\begin{array}{l} \overline{\Delta, E \vdash \ \textbf{field}\ id_i : p\ t\_args \rightarrow t_i \triangleright (x_i\ \textbf{of}\ names)}^{\,i} \\ \overline{\Delta, E, E^{\mathrm{L}} \vdash exp_i : t_i \triangleright \Sigma^{\mathcal{C}}{}_i, \Sigma^{\mathcal{N}}{}_i}^{\,i} \\ \textbf{duplicates}\,(\,\overline{x_i}^{\,i}\,) = \emptyset \\ names = \{\,\overline{x_i}^{\,i}\,\} \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash \langle|\overline{id_i = exp_i\ l_i}^{\,i}\ ;^?\ l|\rangle : p\ t\_args \triangleright \overline{\Sigma^{\mathcal{C}}{}_i}^{\,i}, \overline{\Sigma^{\mathcal{N}}{}_i}^{\,i}} \ \text{CHECK\_EXP\_AUX\_RECORD}$$

$$\frac{\begin{array}{l} \overline{\Delta, E \vdash \ \textbf{field}\ id_i : p\ t\_args \rightarrow t_i \triangleright (x_i\ \textbf{of}\ names)}^{\,i} \\ \overline{\Delta, E, E^{\mathrm{L}} \vdash exp_i : t_i \triangleright \Sigma^{\mathcal{C}}{}_i, \Sigma^{\mathcal{N}}{}_i}^{\,i} \\ \textbf{duplicates}\,(\,\overline{x_i}^{\,i}\,) = \emptyset \\ \Delta, E, E^{\mathrm{L}} \vdash exp : p\ t\_args \triangleright \Sigma^{\mathcal{C}\prime}, \Sigma^{\mathcal{N}\prime} \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash \langle|exp\ \textbf{with}\ \overline{id_i = exp_i\ l_i}^{\,i}\ ;^?\ l|\rangle : p\ t\_args \triangleright \Sigma^{\mathcal{C}\prime} \cup \overline{\Sigma^{\mathcal{C}}{}_i}^{\,i}, \Sigma^{\mathcal{N}\prime} \cup \overline{\Sigma^{\mathcal{N}}{}_i}^{\,i}} \ \text{CHECK\_EXP\_AUX\_RECUP}$$

$$\frac{\begin{array}{l} \Delta, E, E^{\mathrm{L}} \vdash exp_1 : t \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \quad ... \quad \Delta, E, E^{\mathrm{L}} \vdash exp_n : t \triangleright \Sigma^{\mathcal{C}}{}_n, \Sigma^{\mathcal{N}}{}_n \\ \textbf{length}\,(exp_1 \ ... \ exp_n) = nat \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash [|exp_1; \ ...\ ; exp_n\ ;^?|] : \_\_\textbf{vector}\ nat\ t \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \ ... \ \cup \Sigma^{\mathcal{C}}{}_n, \Sigma^{\mathcal{N}}{}_1 \cup \ ... \ \cup \Sigma^{\mathcal{N}}{}_n} \ \text{CHECK\_EXP\_AUX\_VECTOR}$$

$$\frac{\begin{array}{l} \Delta, E, E^{\mathrm{L}} \vdash exp : \_\_\textbf{vector}\ ne'\ t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}} \\ \vdash Nexp \rightsquigarrow ne \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash exp.(Nexp) : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}} \cup \{ne\langle ne'\}} \ \text{CHECK\_EXP\_AUX\_VECTORGET}$$

$$\frac{\begin{array}{l} \Delta, E, E^{\mathrm{L}} \vdash exp : \_\_\textbf{vector}\ ne'\ t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}} \\ \vdash Nexp_1 \rightsquigarrow ne_1 \\ \vdash Nexp_2 \rightsquigarrow ne_2 \\ ne = ne_2 + (-ne_1) \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash exp.(Nexp_1..Nexp_2) : \_\_\textbf{vector}\ ne\ t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}} \cup \{ne_1\langle ne_2\langle ne'\}} \ \text{CHECK\_EXP\_AUX\_VECTORSUB}$$

$$\frac{\begin{array}{l} E \vdash id\ \mathbf{field} \\ \Delta, E \vdash\ \mathbf{field}\ id : p\ t\_args \to t \triangleright (x\ \mathbf{of}\ names) \\ \Delta, E, E^{\mathrm{L}} \vdash exp : p\ t\_args \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}} \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash exp.id : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}\ \text{CHECK\_EXP\_AUX\_FIELD}$$

$$\frac{\begin{array}{l} \overline{\Delta, E, E^{\mathrm{L}} \vdash pat_i : t \triangleright E_i^{\mathrm{L}}}^{\,i} \\ \overline{\Delta, E, E^{\mathrm{L}} \uplus E_i^{\mathrm{L}} \vdash exp_i : u \triangleright \Sigma^{\mathcal{C}}{}_i, \Sigma^{\mathcal{N}}{}_i}^{\,i} \\ \Delta, E, E^{\mathrm{L}} \vdash exp : t \triangleright \Sigma^{\mathcal{C}'}, \Sigma^{\mathcal{N}'} \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash \mathbf{match}\ exp\ \mathbf{with}\ |^{?}\ \overline{pat_i \to exp_i\ l_i}^{\,i}\ l\ \mathbf{end} : u \triangleright \Sigma^{\mathcal{C}'} \cup \overline{\Sigma^{\mathcal{C}}{}_i}^{\,i}, \Sigma^{\mathcal{N}'} \cup \overline{\Sigma^{\mathcal{N}}{}_i}^{\,i}}\ \text{CHECK\_EXP\_AUX\_CASE}$$

$$\frac{\begin{array}{l} \Delta, E, E^{\mathrm{L}} \vdash exp : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}} \\ \Delta, E \vdash typ \rightsquigarrow t \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash (exp : typ) : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}\ \text{CHECK\_EXP\_AUX\_TYPED}$$

$$\frac{\begin{array}{l} \Delta, E, E_1^{\mathrm{L}} \vdash letbind \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \\ \Delta, E, E_1^{\mathrm{L}} \uplus E_2^{\mathrm{L}} \vdash exp : t \triangleright \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2 \end{array}}{\Delta, E, E_1^{\mathrm{L}} \vdash \mathbf{let}\ letbind\ \mathbf{in}\ exp : t \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_1 \cup \Sigma^{\mathcal{N}}{}_2}\ \text{CHECK\_EXP\_AUX\_LET}$$

$$\frac{\Delta, E, E^{\mathrm{L}} \vdash exp_1 : t_1 \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \quad .... \quad \Delta, E, E^{\mathrm{L}} \vdash exp_n : t_n \triangleright \Sigma^{\mathcal{C}}{}_n, \Sigma^{\mathcal{N}}{}_n}{\Delta, E, E^{\mathrm{L}} \vdash (exp_1, ..., exp_n) : t_1 * .... * t_n \triangleright \Sigma^{\mathcal{C}}{}_1 \cup .... \cup \Sigma^{\mathcal{C}}{}_n, \Sigma^{\mathcal{N}}{}_1 \cup .... \cup \Sigma^{\mathcal{N}}{}_n}\ \text{CHECK\_EXP\_AUX\_TUP}$$

$$\frac{\begin{array}{l} \Delta \vdash t\ \mathbf{ok} \\ \Delta, E, E^{\mathrm{L}} \vdash exp_1 : t \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \quad .. \quad \Delta, E, E^{\mathrm{L}} \vdash exp_n : t \triangleright \Sigma^{\mathcal{C}}{}_n, \Sigma^{\mathcal{N}}{}_n \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash [exp_1; ..; exp_n ;^{?}] : \_\_\mathbf{list}\ t \triangleright \Sigma^{\mathcal{C}}{}_1 \cup .. \cup \Sigma^{\mathcal{C}}{}_n, \Sigma^{\mathcal{N}}{}_1 \cup .. \cup \Sigma^{\mathcal{N}}{}_n}\ \text{CHECK\_EXP\_AUX\_LIST}$$

$$\frac{\Delta, E, E^{\mathrm{L}} \vdash exp : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}{\Delta, E, E^{\mathrm{L}} \vdash (exp) : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}\ \text{CHECK\_EXP\_AUX\_PAREN}$$

$$\frac{\Delta, E, E^{\mathrm{L}} \vdash exp : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}{\Delta, E, E^{\mathrm{L}} \vdash \mathbf{begin}\ exp\ \mathbf{end} : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}\ \text{CHECK\_EXP\_AUX\_BEGIN}$$

$$\frac{\begin{array}{l} \Delta, E, E^{\mathrm{L}} \vdash exp_1 : \_\_\mathbf{bool}\ \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \\ \Delta, E, E^{\mathrm{L}} \vdash exp_2 : t \triangleright \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2 \\ \Delta, E, E^{\mathrm{L}} \vdash exp_3 : t \triangleright \Sigma^{\mathcal{C}}{}_3, \Sigma^{\mathcal{N}}{}_3 \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash \mathbf{if}\ exp_1\ \mathbf{then}\ exp_2\ \mathbf{else}\ exp_3 : t \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2 \cup \Sigma^{\mathcal{C}}{}_3, \Sigma^{\mathcal{N}}{}_1 \cup \Sigma^{\mathcal{N}}{}_2 \cup \Sigma^{\mathcal{N}}{}_3}\ \text{CHECK\_EXP\_AUX\_IF}$$

$$\frac{\begin{array}{l} \Delta, E, E^{\mathrm{L}} \vdash exp_1 : t \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \\ \Delta, E, E^{\mathrm{L}} \vdash exp_2 : \_\_\mathbf{list}\ t \triangleright \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2 \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash exp_1 :: exp_2 : \_\_\mathbf{list}\ t \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_1 \cup \Sigma^{\mathcal{N}}{}_2}\ \text{CHECK\_EXP\_AUX\_CONS}$$

$$\frac{\vdash lit : t}{\Delta, E, E^{\mathrm{L}} \vdash lit : t \triangleright \{\,\}, \{\,\}}\ \text{CHECK\_EXP\_AUX\_LIT}$$

$$\frac{\begin{array}{l} \overline{\Delta \vdash t_i\ \mathbf{ok}}^{\,i} \\ \Delta, E, E^{\mathrm{L}} \uplus \{\,\overline{x_i \mapsto t_i}^{\,i}\,\} \vdash exp_1 : t \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \\ \Delta, E, E^{\mathrm{L}} \uplus \{\,\overline{x_i \mapsto t_i}^{\,i}\,\} \vdash exp_2 : \_\_\mathbf{bool}\ \triangleright \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2 \\ \mathbf{disjoint\ doms}\,(E^{\mathrm{L}}, \{\,\overline{x_i \mapsto t_i}^{\,i}\,\}) \\ E = \langle E^{\mathrm{M}}, E^{\mathrm{P}}, E^{\mathrm{F}}, E^{\mathrm{X}} \rangle \\ \overline{x_i \notin \mathbf{dom}\,(E^{\mathrm{X}})}^{\,i} \end{array}}{\Delta, E, E^{\mathrm{L}} \vdash \{exp_1 | exp_2\} : \_\_\mathbf{set}\ t \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_1 \cup \Sigma^{\mathcal{N}}{}_2}\ \text{CHECK\_EXP\_AUX\_SET\_COMP}$$

$$\frac{\begin{array}{l} \Delta, E, E_1^{\mathrm{L}} \vdash\ \overline{qbind_i}^{\,i} \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_1 \\ \Delta, E, E_1^{\mathrm{L}} \uplus E_2^{\mathrm{L}} \vdash exp_1 : t \triangleright \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2 \\ \Delta, E, E_1^{\mathrm{L}} \uplus E_2^{\mathrm{L}} \vdash exp_2 : \_\_\mathbf{bool}\ \triangleright \Sigma^{\mathcal{C}}{}_3, \Sigma^{\mathcal{N}}{}_3 \end{array}}{\Delta, E, E_1^{\mathrm{L}} \vdash \{exp_1 |\, \mathbf{forall}\ \overline{qbind_i}^{\,i}\, | exp_2\} : \_\_\mathbf{set}\ t \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2 \cup \Sigma^{\mathcal{C}}{}_3, \Sigma^{\mathcal{N}}{}_2 \cup \Sigma^{\mathcal{N}}{}_3}\ \text{CHECK\_EXP\_AUX\_SET\_COMP\_}$$

$$\frac{\Delta \vdash t\ \mathbf{ok} \quad \Delta, E, E^{\mathrm{L}} \vdash exp_1 : t \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \quad .. \quad \Delta, E, E^{\mathrm{L}} \vdash exp_n : t \triangleright \Sigma^{\mathcal{C}}{}_n, \Sigma^{\mathcal{N}}{}_n}{\Delta, E, E^{\mathrm{L}} \vdash \{exp_1; \ldots; exp_n\ ;^{?}\} : \_\_\mathbf{set}\ t \triangleright \Sigma^{\mathcal{C}}{}_1 \cup .. \cup \Sigma^{\mathcal{C}}{}_n, \Sigma^{\mathcal{N}}{}_1 \cup .. \cup \Sigma^{\mathcal{N}}{}_n}\ \text{CHECK\_EXP\_AUX\_SET}$$

$$\frac{\Delta, E, E_1^{\mathrm{L}} \vdash \overline{qbind_i}^{\,i} \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_1 \quad \Delta, E, E_1^{\mathrm{L}} \uplus E_2^{\mathrm{L}} \vdash exp : \_\_\mathbf{bool}\ \triangleright \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2}{\Delta, E, E_1^{\mathrm{L}} \vdash q\ \overline{qbind_i}^{\,i}\ .exp : \_\_\mathbf{bool}\ \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2}\ \text{CHECK\_EXP\_AUX\_QUANT}$$

$$\frac{\Delta, E, E_1^{\mathrm{L}} \vdash \mathbf{list}\ \overline{qbind_i}^{\,i} \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_1 \quad \Delta, E, E_1^{\mathrm{L}} \uplus E_2^{\mathrm{L}} \vdash exp_1 : t \triangleright \Sigma^{\mathcal{C}}{}_2, \Sigma^{\mathcal{N}}{}_2 \quad \Delta, E, E_1^{\mathrm{L}} \uplus E_2^{\mathrm{L}} \vdash exp_2 : \_\_\mathbf{bool}\ \triangleright \Sigma^{\mathcal{C}}{}_3, \Sigma^{\mathcal{N}}{}_3}{\Delta, E, E_1^{\mathrm{L}} \vdash [exp_1 |\, \mathbf{forall}\ \overline{qbind_i}^{\,i}\, | exp_2] : \_\_\mathbf{list}\ t \triangleright \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2 \cup \Sigma^{\mathcal{C}}{}_3, \Sigma^{\mathcal{N}}{}_2 \cup \Sigma^{\mathcal{N}}{}_3}\ \text{CHECK\_EXP\_AUX\_LIST\_COMP\_}$$

$\boxed{\Delta, E, E_1^{\mathrm{L}} \vdash qbind_1 .. qbind_n \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}}$ Build the environment for quantifier bindings, collecting typeclass cons

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

$$\frac{\Delta \vdash t\ \mathbf{ok} \quad \Delta, E, E_1^{\mathrm{L}} \uplus \{x \mapsto t\} \vdash \overline{qbind_i}^{\,i} \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_1 \quad \mathbf{disjoint\ doms}\ (\{x \mapsto t\}, E_2^{\mathrm{L}})}{\Delta, E, E_1^{\mathrm{L}} \vdash x\ l\ \overline{qbind_i}^{\,i} \triangleright \{x \mapsto t\} \uplus E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_1}\ \text{CHECK\_LISTQUANT\_BINDING\_VAR}$$

$$\frac{\Delta, E, E_1^{\mathrm{L}} \vdash pat : t \triangleright E_3^{\mathrm{L}} \quad \Delta, E, E_1^{\mathrm{L}} \vdash exp : \_\_\mathbf{set}\ t \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \quad \Delta, E, E_1^{\mathrm{L}} \uplus E_3^{\mathrm{L}} \vdash \overline{qbind_i}^{\,i} \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_2 \quad \mathbf{disjoint\ doms}\ (E_3^{\mathrm{L}}, E_2^{\mathrm{L}})}{\Delta, E, E_1^{\mathrm{L}} \vdash (pat\ \mathbf{IN}\ exp)\ \overline{qbind_i}^{\,i} \triangleright E_2^{\mathrm{L}} \uplus E_3^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2}\ \text{CHECK\_LISTQUANT\_BINDING\_RESTR}$$

$$\frac{\Delta, E, E_1^{\mathrm{L}} \vdash pat : t \triangleright E_3^{\mathrm{L}} \quad \Delta, E, E_1^{\mathrm{L}} \vdash exp : \_\_\mathbf{list}\ t \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \quad \Delta, E, E_1^{\mathrm{L}} \uplus E_3^{\mathrm{L}} \vdash \overline{qbind_i}^{\,i} \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_2 \quad \mathbf{disjoint\ doms}\ (E_3^{\mathrm{L}}, E_2^{\mathrm{L}})}{\Delta, E, E_1^{\mathrm{L}} \vdash (pat\ \mathbf{MEM}\ exp)\ \overline{qbind_i}^{\,i} \triangleright E_2^{\mathrm{L}} \uplus E_3^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2}\ \text{CHECK\_LISTQUANT\_BINDING\_LIST\_RESTR}$$

$\boxed{\Delta, E, E_1^{\mathrm{L}} \vdash \mathbf{list}\ qbind_1 .. qbind_n \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}}$ Build the environment for quantifier bindings, collecting typeclass

$$\frac{}{\Delta, E, E^{\mathrm{L}} \vdash \mathbf{list}\ \triangleright \{\,\}, \{\,\}}\ \text{CHECK\_QUANT\_BINDING\_EMPTY}$$

$$\frac{\Delta, E, E_1^{\mathrm{L}} \vdash pat : t \triangleright E_3^{\mathrm{L}} \quad \Delta, E, E_1^{\mathrm{L}} \vdash exp : \_\_\mathbf{list}\ t \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \quad \Delta, E, E_1^{\mathrm{L}} \uplus E_3^{\mathrm{L}} \vdash \overline{qbind_i}^{\,i} \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_2 \quad \mathbf{disjoint\ doms}\ (E_3^{\mathrm{L}}, E_2^{\mathrm{L}})}{\Delta, E, E_1^{\mathrm{L}} \vdash \mathbf{list}\ (pat\ \mathbf{MEM}\ exp)\ \overline{qbind_i}^{\,i} \triangleright E_2^{\mathrm{L}} \uplus E_3^{\mathrm{L}}, \Sigma^{\mathcal{C}}{}_1 \cup \Sigma^{\mathcal{C}}{}_2}\ \text{CHECK\_QUANT\_BINDING\_RESTR}$$

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

$$\frac{\Delta, E, E^{\mathrm{L}} \vdash pat_1 : t_1 \triangleright E_1^{\mathrm{L}} \quad \ldots \quad \Delta, E, E^{\mathrm{L}} \vdash pat_n : t_n \triangleright E_n^{\mathrm{L}} \quad \Delta, E, E^{\mathrm{L}} \uplus E_1^{\mathrm{L}} \uplus \ldots \uplus E_n^{\mathrm{L}} \vdash exp : u \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}} \quad \mathbf{disjoint\ doms}\ (E_1^{\mathrm{L}}, \ldots, E_n^{\mathrm{L}}) \quad \Delta, E \vdash typ \rightsquigarrow u}{\Delta, E, E^{\mathrm{L}} \vdash x\ l_1\ pat_1 \ldots pat_n\ : typ = exp\ l_2 \triangleright \{x \mapsto \mathbf{curry}\ ((t_1 * \ldots * t_n), u)\}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}\ \text{CHECK\_FUNCL\_ANNOT}$$

$$\frac{\begin{array}{l}\Delta, E, E^{\mathrm{L}} \vdash pat_1 : t_1 \triangleright E_1^{\mathrm{L}} \quad ... \quad \Delta, E, E^{\mathrm{L}} \vdash pat_n : t_n \triangleright E_n^{\mathrm{L}} \\ \Delta, E, E^{\mathrm{L}} \uplus E_1^{\mathrm{L}} \uplus ... \uplus E_n^{\mathrm{L}} \vdash exp : u \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}} \\ \mathbf{disjoint\ doms}\,(E_1^{\mathrm{L}}, ..., E_n^{\mathrm{L}})\end{array}}{\Delta, E, E^{\mathrm{L}} \vdash x\ l_1\ pat_1 ...\ pat_n\ = exp\ l_2 \triangleright \{x \mapsto \mathbf{curry}\,((t_1 * ... * t_n), u)\}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}\ \text{CHECK\_FUNCL\_NOANNOT}$$

$\boxed{\Delta, E, E_1^{\mathrm{L}} \vdash letbind \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}$ Build the environment for a let binding, collecting typeclass and index con

$$\frac{\begin{array}{l}\Delta, E, E_1^{\mathrm{L}} \vdash pat : t \triangleright E_2^{\mathrm{L}} \\ \Delta, E, E_1^{\mathrm{L}} \vdash exp : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}} \\ \Delta, E \vdash typ \rightsquigarrow t\end{array}}{\Delta, E, E_1^{\mathrm{L}} \vdash pat\ : typ = exp\ l \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}\ \text{CHECK\_LETBIND\_VAL\_ANNOT}$$

$$\frac{\begin{array}{l}\Delta, E, E_1^{\mathrm{L}} \vdash pat : t \triangleright E_2^{\mathrm{L}} \\ \Delta, E, E_1^{\mathrm{L}} \vdash exp : t \triangleright \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}\end{array}}{\Delta, E, E_1^{\mathrm{L}} \vdash pat\ = exp\ l \triangleright E_2^{\mathrm{L}}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}\ \text{CHECK\_LETBIND\_VAL\_NOANNOT}$$

$$\frac{\Delta, E, E_1^{\mathrm{L}} \vdash funcl\_aux\ l \triangleright \{x \mapsto t\}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}{\Delta, E, E_1^{\mathrm{L}} \vdash funcl\_aux\ l \triangleright \{x \mapsto t\}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}\ \text{CHECK\_LETBIND\_FN}$$

$\boxed{\Delta, E, E^{\mathrm{L}} \vdash rule \triangleright \{x \mapsto t\}, \Sigma^{\mathcal{C}}, \Sigma^{\mathcal{N}}}$ Build the environment for an inductive relation clause, collecting typecl

$$\frac{\begin{array}{l}\overline{\Delta \vdash t_i\ \mathbf{ok}}^{\,i} \\ E_2^{\mathrm{L}} = \{\ \overline{name\_t_i \rightarrow x\ \mapsto t_i}^{\,i}\ \} \\ \Delta, E, E_1^{\mathrm{L}} \uplus E_2^{\mathrm{L}} \vdash exp' : \_\_\mathbf{bool}\ \triangleright \Sigma^{\mathcal{C}\prime}, \Sigma^{\mathcal{N}\prime} \\ \Delta, E, E_1^{\mathrm{L}} \uplus E_2^{\mathrm{L}} \vdash exp_1 : u_1 \triangleright \Sigma^{\mathcal{C}}{}_1, \Sigma^{\mathcal{N}}{}_1 \quad .. \quad \Delta, E, E_1^{\mathrm{L}} \uplus E_2^{\mathrm{L}} \vdash exp_n : u_n \triangleright \Sigma^{\mathcal{C}}{}_n, \Sigma^{\mathcal{N}}\end{array}}{\Delta, E, E_1^{\mathrm{L}} \vdash x_1^l : \mathbf{forall}\ \overline{name\_t_i}^{\,i}\ .exp' \Longrightarrow x\ l\ exp_1\ ..\ exp_n\ l' \triangleright \{x \mapsto \mathbf{curry}\,((u_1 * .. * u_n), \_\_\mathbf{bool}\ )\}, \Sigma^{\mathcal{C}\prime} \cup \Sigma^{\mathcal{C}}{}_1 \cup}$$

$\boxed{xs, \Delta_1, E \vdash\ \mathbf{tc}\ td \triangleright \Delta_2, E^{\mathrm{P}}}$ Extract the type constructor information

$$\frac{\begin{array}{l}tnvars^l \rightsquigarrow tnvs \\ \Delta, E \vdash typ \rightsquigarrow t \\ \mathbf{duplicates}\,(tnvs) = \emptyset \\ \mathbf{FV}\,(t)\ \subset\ tnvs \\ \overline{y_i.}^{\,i}\ x\ \notin\ \mathbf{dom}\,(\Delta)\end{array}}{\overline{y_i}^{\,i}, \Delta, E \vdash\ \mathbf{tc}\ x\ l\ tnvars^l\ = typ \triangleright \{\overline{y_i.}^{\,i}\ x \mapsto tnvs\ .t\}, \{x \mapsto \overline{y_i.}^{\,i}\ x\}}\ \text{CHECK\_TEXP\_TC\_ABBREV}$$

$$\frac{\begin{array}{l}tnvars^l \rightsquigarrow tnvs \\ \mathbf{duplicates}\,(tnvs) = \emptyset \\ \overline{y_i.}^{\,i}\ x\ \notin\ \mathbf{dom}\,(\Delta)\end{array}}{\overline{y_i}^{\,i}, \Delta, E_1 \vdash\ \mathbf{tc}\ x\ l\ tnvars^l\ \triangleright \{\overline{y_i.}^{\,i}\ x \mapsto tnvs\ \}, \{x \mapsto \overline{y_i.}^{\,i}\ x\}}\ \text{CHECK\_TEXP\_TC\_ABSTRACT}$$

$$\frac{\begin{array}{l}tnvars^l \rightsquigarrow tnvs \\ \mathbf{duplicates}\,(tnvs) = \emptyset \\ \overline{y_i.}^{\,i}\ x\ \notin\ \mathbf{dom}\,(\Delta)\end{array}}{\overline{y_i}^{\,i}, \Delta_1, E \vdash\ \mathbf{tc}\ x\ l\ tnvars^l\ = \langle |x_1^l : typ_1; ...; x_j^l : typ_j\ ;^? | \rangle \triangleright \{\overline{y_i.}^{\,i}\ x \mapsto tnvs\ \}, \{x \mapsto \overline{y_i.}^{\,i}\ x\}}\ \text{CHECK\_TEXP\_TC\_REC}$$

$$\frac{\begin{array}{l}tnvars^l \rightsquigarrow tnvs \\ \mathbf{duplicates}\,(tnvs) = \emptyset \\ \overline{y_i.}^{\,i}\ x\ \notin\ \mathbf{dom}\,(\Delta)\end{array}}{\overline{y_i}^{\,i}, \Delta_1, E \vdash\ \mathbf{tc}\ x\ l\ tnvars^l\ = |^?\ ctor\_def_1| ... |ctor\_def_j \triangleright \{\overline{y_i.}^{\,i}\ x \mapsto tnvs\ \}, \{x \mapsto \overline{y_i.}^{\,i}\ x\}}\ \text{CHECK\_TEXP\_TC\_VAR}$$

$\boxed{xs, \Delta_1, E \vdash\ \mathbf{tc}\ td_1\ ..\ td_i \triangleright \Delta_2, E^{\mathrm{P}}}$ Extract the type constructor information

$$\frac{}{xs, \Delta, E \vdash\ \mathbf{tc} \triangleright \{\ \}, \{\ \}}\ \text{CHECK\_TEXPS\_TC\_EMPTY}$$

$$\frac{\begin{array}{l} xs, \Delta_1, E \vdash \mathbf{tc}\ td \triangleright \Delta_2, E_2^{\mathrm{P}} \\ xs, \Delta_1 \uplus \Delta_2, E \uplus \langle \{\,\}, E_2^{\mathrm{P}}, \{\,\}, \{\,\}\rangle \vdash \mathbf{tc}\ \overline{td_i}^{\,i} \triangleright \Delta_3, E_3^{\mathrm{P}} \\ \mathbf{dom}\,(E_2^{\mathrm{P}}) \cap \mathbf{dom}\,(E_3^{\mathrm{P}}) = \emptyset \end{array}}{xs, \Delta_1, E \vdash \mathbf{tc}\ td\ \overline{td_i}^{\,i} \triangleright \Delta_2 \uplus \Delta_3, E_2^{\mathrm{P}} \uplus E_3^{\mathrm{P}}}\ \textsc{check\_texps\_tc\_abbrev}$$

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

$$\frac{}{\Delta, E \vdash tnvs\ p = typ \triangleright \langle \{\,\}, \{\,\}\rangle}\ \textsc{check\_texp\_abbrev}$$

$$\frac{\begin{array}{l} \overline{\Delta, E \vdash typ_i \rightsquigarrow t_i}^{\,i} \\ names = \{\,\overline{x_i}^{\,i}\,\} \\ \mathbf{duplicates}\,(\,\overline{x_i}^{\,i}\,) = \emptyset \\ \overline{\mathbf{FV}\,(t_i) \subset tnvs}^{\,i} \\ E^{\mathrm{F}} = \{\,\overline{x_i \mapsto \langle\, \mathbf{forall}\ tnvs.p \to t_i, (x_i\ \mathbf{of}\ names)\rangle}^{\,i}\,\} \end{array}}{\Delta, E \vdash tnvs\ p = \langle|\ \overline{x_i^l : typ_i}^{\,i}\ ;^?|\rangle \triangleright \langle E^{\mathrm{F}}, \{\,\}\rangle}\ \textsc{check\_texp\_rec}$$

$$\frac{\begin{array}{l} \overline{\Delta, E \vdash typs_i \rightsquigarrow t\_multi_i}^{\,i} \\ names = \{\,\overline{x_i}^{\,i}\,\} \\ \mathbf{duplicates}\,(\,\overline{x_i}^{\,i}\,) = \emptyset \\ \overline{\mathbf{FV}\,(t\_multi_i) \subset tnvs}^{\,i} \\ E^{\mathrm{X}} = \{\,\overline{x_i \mapsto \langle\, \mathbf{forall}\ tnvs.t\_multi_i \to p, (x_i\ \mathbf{of}\ names)\rangle}^{\,i}\,\} \end{array}}{\Delta, E \vdash tnvs\ p = |^?\ \overline{x_i^l\ \mathbf{of}\ typs_i}^{\,i} \triangleright \langle \{\,\}, E^{\mathrm{X}}\rangle}\ \textsc{check\_texp\_var}$$

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

$$\frac{}{\overline{y_i}^{\,i}, \Delta, E \vdash \triangleright \langle \{\,\}, \{\,\}\rangle}\ \textsc{check\_texps\_empty}$$

$$\frac{\begin{array}{l} tnvars^l \rightsquigarrow tnvs \\ \Delta, E_1 \vdash tnvs\ \overline{y_i.}^{\,i}\ x = texp \triangleright \langle E_1^{\mathrm{F}}, E_1^{\mathrm{X}}\rangle \\ \overline{y_i}^{\,i}, \Delta, E \vdash \overline{td_j}^{\,j} \triangleright \langle E_2^{\mathrm{F}}, E_2^{\mathrm{X}}\rangle \\ \mathbf{dom}\,(E_1^{\mathrm{X}}) \cap \mathbf{dom}\,(E_2^{\mathrm{X}}) = \emptyset \\ \mathbf{dom}\,(E_1^{\mathrm{F}}) \cap \mathbf{dom}\,(E_2^{\mathrm{F}}) = \emptyset \end{array}}{\overline{y_i}^{\,i}, \Delta, E \vdash x\ l\ tnvars^l\ = texp\ \overline{td_j}^{\,j} \triangleright \langle E_1^{\mathrm{F}} \uplus E_2^{\mathrm{F}}, E_1^{\mathrm{X}} \uplus E_2^{\mathrm{X}}\rangle}\ \textsc{check\_texps\_cons\_concrete}$$

$$\frac{\overline{y_i}^{\,i}, \Delta, E \vdash \overline{td_j}^{\,j} \triangleright \langle E^{\mathrm{F}}, E^{\mathrm{X}}\rangle}{\overline{y_i}^{\,i}, \Delta, E \vdash x\ l\ tnvars^l\ \overline{td_j}^{\,j} \triangleright \langle E^{\mathrm{F}}, E^{\mathrm{X}}\rangle}\ \textsc{check\_texps\_cons\_abstract}$$

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

$$\frac{\begin{array}{l} E(id) \triangleright p \\ \delta(p) \triangleright xs \end{array}}{\delta, E \vdash id \rightsquigarrow p}\ \textsc{convert\_class\_all}$$

$\boxed{I \vdash (p\ t)\ \mathbf{IN}\ \mathcal{C}}$ Solve class constraint

$$\frac{}{I \vdash (p\ \alpha)\ \mathbf{IN}\ (p_1\ tnv_1)\ ..\ (p_i\ tnv_i)(p\ \alpha)(p'_1\ tnv'_1)\ ..\ (p'_j\ tnv'_j)}\ \textsc{solve\_class\_constraint\_immediate}$$

$$\frac{\begin{array}{l} (p_1\ tnv_1)\ ..\ (p_n\ tnv_n) \Rightarrow (p\ t)\ \mathbf{IN}\ I \\ I \vdash (p_1\ \sigma(tnv_1))\ \mathbf{IN}\ \mathcal{C} \quad .. \quad I \vdash (p_n\ \sigma(tnv_n))\ \mathbf{IN}\ \mathcal{C} \end{array}}{I \vdash (p\ \sigma(t))\ \mathbf{IN}\ \mathcal{C}}\ \textsc{solve\_class\_constraint\_chain}$$

$\boxed{I \vdash \Sigma^{\mathcal{C}} \triangleright \mathcal{C}}$ Solve class constraints

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

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

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

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

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

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

$$\frac{}{\Delta, (\alpha_1, \ldots., \alpha_n) \vdash \alpha_1 * \ldots. * \alpha_n\ \mathbf{instance}}\ \text{CHECK\_T\_INSTANCE\_TUP}$$

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

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

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

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

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

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

<<no parses (char 59): </zj//j/>,<TD,TC,I>,E1 |- indreln targets_opt indreln_names*** </rulei

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

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

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

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

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

$\boxed{\overline{z_j}^{\,j}, D_1, E_1 \vdash \mathit{defs} \triangleright D_2, E_2}$ Check definitions, given module path, definitions and environment

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

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

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

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Definition rules:          144 good    1 bad
Definition rule clauses:   438 good    1 bad
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