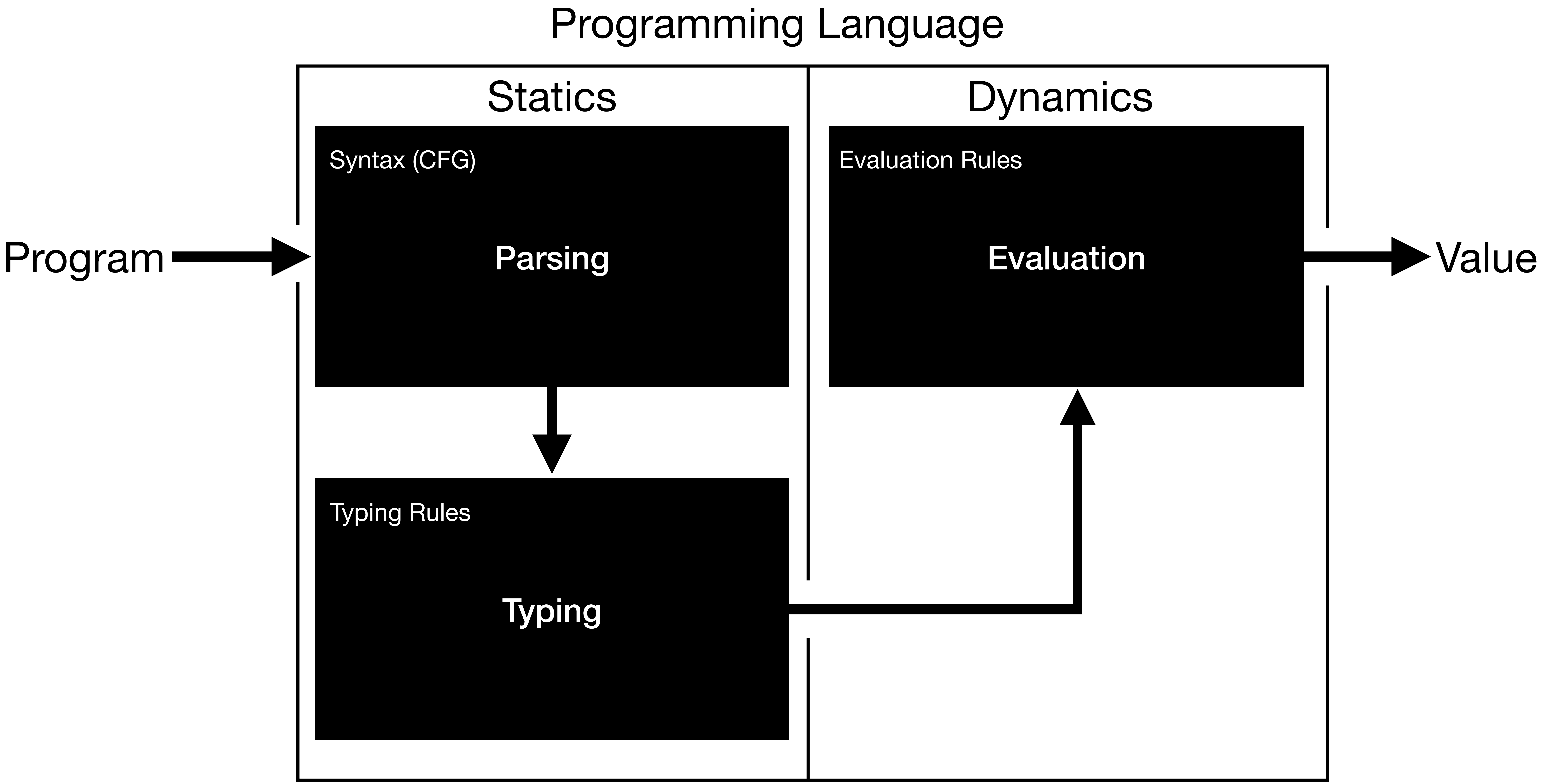
Object-Oriented Programming

Harley Eades III



Programming Language

Statics

Dynamics

Program

Syntax (CFG)

Parsing

Typing Rules

Typing

Evaluation Rules

Evaluation

Value

Part 1:Pairs

New Syntactic Forms: Adding Pairs

Terms

$$
\begin{aligned}
t ::=\ & \mathrm{T} \\
\mid\ & \mathrm{F} \\
\mid\ & \text{if } t_1 \text{ then } t_2 \text{ else } t_3 \\
\mid\ & x \\
\mid\ & \text{fun}\, x : T \rightarrow \{t\} \\
\mid\ & t_1\ t_2 \\
\mid\ & (t_1, t_2) \\
\mid\ & t.1 \\
\mid\ & t.2 \\
\mid\ & \text{let}\, x = t_1 \text{ in } t_2
\end{aligned}
$$

Values

$$
\begin{aligned}
v ::=\ & \mathrm{T} \\
\mid\ & \mathrm{F} \\
\mid\ & \text{fun}\, x : T \rightarrow \{t\} \\
\mid\ & (v_1, v_2)
\end{aligned}
$$

Types

$$
\begin{aligned}
T ::=\ & \mathrm{Bool} \\
\mid\ & (T_1, T_2) \\
\mid\ & T_1 \rightarrow T_2
\end{aligned}
$$

Example Programs

$$\begin{aligned}&\text{let twist} = \text{fun}\, p : (\text{Bool}, \text{Bool}) \to \{(p.2, p.1)\}\\ &\qquad\qquad \text{in twist}\,(\text{T}, \text{F})\end{aligned}$$

$$\begin{aligned}&\text{let second} = \text{fun}\, p : (\text{Bool} \to \text{Bool}, \text{Bool}) \to \{\text{if}\, p.2\, \text{then}\, p.1\, \text{T else F}\}\\ &\qquad\qquad \text{in second}\,(\text{fun}\, x : \text{Bool} \to \{\text{if}\, x\, \text{then F else T}\}, \text{T})\end{aligned}$$

Statics: Bools

$$\frac{\Gamma \vdash t_1 : \text{Bool} \qquad \Gamma \vdash t_2 : T \qquad \Gamma \vdash t_3 : T}{\Gamma \vdash \text{if } t_1 \text{ then } t_2 \text{ else } t_3 : T}\ \text{If}$$

$$\frac{}{\Gamma \vdash \text{T} : \text{Bool}}\ \text{T}$$

$$\frac{}{\Gamma \vdash \text{F} : \text{Bool}}\ \text{F}$$

Statics: Functions

$$\frac{}{\Gamma_1, x : T, \Gamma_2 \vdash x : T}\ \text{Var}$$

$$\frac{\Gamma, x : T_1 \vdash t : T_2}{\Gamma \vdash \mathsf{fun}\, x : T_1 \rightarrow \{t\} : T_1 \rightarrow T_2}\ \text{Fun}$$

$$\frac{\Gamma \vdash t_1 : T_1 \rightarrow T_2 \quad \Gamma \vdash t_2 : T_1}{\Gamma \vdash t_1\, t_2 : T_2}\ \text{App}$$

$$\frac{\Gamma \vdash t_1 : T_1 \qquad \Gamma, x : T_1 \vdash t_2 : T_2}{\Gamma \vdash \mathsf{let}\, x = t_1\, \mathsf{in}\, t_2 : T_2}\ \text{Let}$$

Statics: Pairs

$$\frac{\Gamma \vdash t_1 : T_1 \qquad \Gamma \vdash t_2 : T_2}{\Gamma \vdash (t_1, t_2) : (T_1, T_2)}\ \text{Pair}$$

$$\frac{\Gamma \vdash t : (T_1, T_2)}{\Gamma \vdash t.1 : T_1}\ \text{First}$$

$$\frac{\Gamma \vdash t : (T_1, T_2)}{\Gamma \vdash t.2 : T_2}\ \text{Second}$$

Call-by-Value Dynamics: Bools

$$\frac{t_1 \rightsquigarrow t_1'}{\mathsf{if}\ t_1\ \mathsf{then}\ t_2\ \mathsf{else}\ t_3 \rightsquigarrow \mathsf{if}\ t_1'\ \mathsf{then}\ t_2\ \mathsf{else}\ t_3}\ \text{If}$$

$$\frac{}{\mathsf{if}\ \mathsf{T}\ \mathsf{then}\ t_2\ \mathsf{else}\ t_3 \rightsquigarrow t_2}\ \text{IfT}$$

$$\frac{}{\mathsf{if}\ \mathsf{F}\ \mathsf{then}\ t_2\ \mathsf{else}\ t_3 \rightsquigarrow t_3}\ \text{IfF}$$

Call-by-Value Dynamics: Functions

$$\frac{t_1 \rightsquigarrow t_1'}{t_1\,t_2 \rightsquigarrow t_1'\,t_2}\;\text{App1}$$

$$\frac{t_2 \rightsquigarrow t_2'}{v_1\,t_2 \rightsquigarrow v_1\,t_2'}\;\text{App2}$$

$$\frac{t_1 \rightsquigarrow t_1'}{\mathsf{let}\,x = t_1\,\mathsf{in}\,t_2 \rightsquigarrow \mathsf{let}\,x = t_1'\,\mathsf{in}\,t_2}\;\text{Let}$$

$$\frac{}{\mathsf{let}\,x = v\,\mathsf{in}\,t \rightsquigarrow [v/x]t}\;\text{Let}\beta$$

$$\frac{}{(\mathsf{fun}\,x : T \rightarrow \{t\})\,v \rightsquigarrow [v/x]t}\;\beta$$

Call-by-Value Dynamics: Pairs

$$\frac{t_1 \rightsquigarrow t_1'}{(t_1, t_2) \rightsquigarrow (t_1', t_2)}\ \text{Pair1}$$

$$\frac{t \rightsquigarrow t'}{t.1 \rightsquigarrow t'.1}\ \text{Proj1}$$

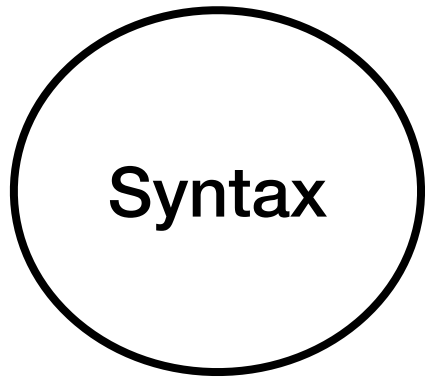
$$\frac{}{(v_1, v_2).1 \rightsquigarrow v_1}\ \text{Pair}\beta_1$$

$$\frac{t_2 \rightsquigarrow t_2'}{(v_1, t_2) \rightsquigarrow (v_1, t_2')}\ \text{Pair2}$$

$$\frac{t \rightsquigarrow t'}{t.2 \rightsquigarrow t'.2}\ \text{Proj2}$$

$$\frac{}{(v_1, v_2).2 \rightsquigarrow v_2}\ \text{Pair}\beta_2$$

Core Design Concepts:



Syntax

Part 2:Unit

New Syntactic Forms: Adding Unit

Terms

t ::= T
| F
| if t_1 then t_2 else t_3
| x
| fun $x : T \to \{t\}$
| $t_1\ t_2$
| $()$
| match $t_1 \{ () \to t_2 \}$
| (t_1, t_2)
| $t.1$
| $t.2$
| let $x = t_1$ in t_2

Values

v ::= T
| F
| fun $x : T \to \{t\}$
| (v_1, v_2)
| $()$

Types

T ::= Bool
| $()$
| (T_1, T_2)
| $T_1 \to T_2$

Example: Sequence

$$t_1; t_2 = (\text{let}\, x = t_1 \text{ in } t_2)$$

$$\frac{\Gamma \vdash t_1 : T_1 \qquad \Gamma \vdash t_2 : ()}{\Gamma \vdash t_1; t_2 : ()}\text{ Seq}$$

$$\text{let}\, x = t_1; t_2 = (\text{let}\, x = t_1 \text{ in } t_2)$$

$$\frac{\Gamma \vdash t_1 : T_1 \qquad \Gamma, x : T_1 \vdash t_2 : ()}{\Gamma \vdash \text{let}\, x = t_1; t_2 : ()}\text{ Define}$$

Example: Sequencing Programs

$$\frac{\Gamma \vdash t : \text{String}}{\Gamma \vdash \text{print}\, t : ()}\ \text{Print}$$

$$\begin{array}{l}
\text{let twist} = \text{fun}\, p : (\text{Bool}, \text{Bool}) \rightarrow \{(p.2, p.1\};\\
\text{let second} = \text{fun}\, p : (\text{Bool} \rightarrow \text{Bool}, \text{Bool}) \rightarrow \{\text{if}\, p.2\, \text{then}\, p.1\, \text{T else F}\};\\
\text{if (second (fun}\, x : \text{Bool} \rightarrow \{x\}, \text{T)) then } \underline{\text{print "True"}} \text{ else } \underline{\text{print"False"}}
\end{array}$$

Statics: Bools

$$\frac{\Gamma \vdash t_1 : \mathsf{Bool} \qquad \Gamma \vdash t_2 : T \qquad \Gamma \vdash t_3 : T}{\Gamma \vdash \mathsf{if}\ t_1\ \mathsf{then}\ t_2\ \mathsf{else}\ t_3 : T}\ \text{If}$$

$$\frac{}{\Gamma \vdash \mathsf{T} : \mathsf{Bool}}\ \text{T}$$

$$\frac{}{\Gamma \vdash \mathsf{F} : \mathsf{Bool}}\ \text{F}$$

Statics: Functions

$$\frac{}{\Gamma_1, x : T, \Gamma_2 \vdash x : T}\ \textsf{Var}$$

$$\frac{\Gamma, x : T_1 \vdash t : T_2}{\Gamma \vdash \textsf{fun}\, x : T_1 \to \{t\} : T_1 \to T_2}\ \textsf{Fun}$$

$$\frac{\Gamma \vdash t_1 : T_1 \to T_2 \qquad \Gamma \vdash t_2 : T}{\Gamma \vdash t_1\, t_2 : T_2}\ \textsf{App}$$

$$\frac{\Gamma \vdash t_1 : T_1 \qquad \Gamma, x : T_1 \vdash t : T_2}{\Gamma \vdash \textsf{let}\, x = t_1\, \textsf{in}\, t_2 : T}\ \textsf{Let}$$

Statics: Pairs

$$\frac{\Gamma \vdash t_1 : T_1 \quad \Gamma \vdash t_2 : T_2}{\Gamma \vdash (t_1, t_2) : (T_1, T_2)}\ \text{Pair}$$

$$\frac{\Gamma \vdash t : (T_1, T_2)}{\Gamma \vdash t.1 : T_1}\ \text{First}$$

$$\frac{\Gamma \vdash t : (T_1, T_2)}{\Gamma \vdash t.2 : T_2}\ \text{Second}$$

Statics: Unit

$$\frac{}{\Gamma \vdash () : ()}\ \text{Unit} \qquad \frac{\Gamma \vdash t_1 : () \qquad \Gamma \vdash t_2 : T}{\Gamma \vdash \mathsf{match}\ t_1 \{() \rightarrow t_2\} : T}\ \text{Match}$$

Call-by-Value Dynamics: Bools

$$\frac{t_1 \rightsquigarrow t_1'}{\text{if } t_1 \text{ then } t_2 \text{ else } t_3 \rightsquigarrow \text{if } t_1' \text{ then } t_2 \text{ else } t_3}\,\text{If}$$

$$\frac{}{\text{if T then } t_2 \text{ else } t_3 \rightsquigarrow t_2}\,\text{IfT}$$

$$\frac{}{\text{if F then } t_2 \text{ else } t_3 \rightsquigarrow t_3}\,\text{IfF}$$

Call-by-Value Dynamics: Functions

$$\frac{t_1 \rightsquigarrow t_1'}{t_1\, t_2 \rightsquigarrow t_1'\, t_2}\ \text{App1}$$

$$\frac{}{\mathsf{let}\, x = v\, \mathsf{in}\, t \rightsquigarrow [v/x]t}\ \text{Let}\beta$$

$$\frac{t_2 \rightsquigarrow t_2'}{v_1\, t_2 \rightsquigarrow v_1\, t_2'}\ \text{App2}$$

$$\frac{}{(\mathsf{fun}\, x : T \rightarrow \{t\})\, v \rightsquigarrow [v/x]t}\ \beta$$

$$\frac{t_1 \rightsquigarrow t_1'}{\mathsf{let}\, x = t_1\, \mathsf{in}\, t_2 \rightsquigarrow \mathsf{let}\, x = t_1'\, \mathsf{in}\, t_2}\ \text{Let}$$

Call-by-Value Dynamics: Pairs

$$\frac{t_1 \rightsquigarrow t_1'}{(t_1, t_2) \rightsquigarrow (t_1', t_2)}\ \text{Pair1} \qquad \frac{t \rightsquigarrow t'}{t.1 \rightsquigarrow t'.1}\ \text{Proj1} \qquad \frac{}{(v_1, v_2).1 \rightsquigarrow v_1}\ \text{Pair}\beta_1$$

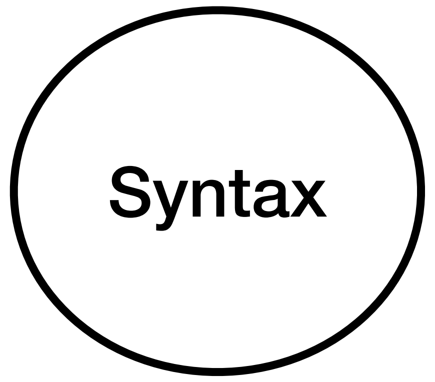
$$\frac{t_2 \rightsquigarrow t_2'}{(v_1, t_2) \rightsquigarrow (v_1, t_2')}\ \text{Pair2} \qquad \frac{t \rightsquigarrow t'}{t.2 \rightsquigarrow t'.2}\ \text{Proj2} \qquad \frac{}{(v_1, v_2).2 \rightsquigarrow v_2}\ \text{Pair}\beta_2$$

Call-by-Value Dynamics: Unit

$$\frac{t_1 \rightsquigarrow t_1'}{\mathsf{match}\; t_1 \{() \to t_2\} \rightsquigarrow \mathsf{match}\; t_1' \{() \to t_2\}}\;\text{Match}$$

$$\frac{}{\mathsf{match}\; () \{() \to t_2\} \rightsquigarrow t_2}\;\text{Unit}\beta$$

Core Design Concepts:



Syntax

Part 3:Tuples

New Syntactic Forms: Adding Tuples

Terms

$$
\begin{aligned}
t ::= {} & \mathsf{T} \\
| {} & \mathsf{F} \\
| {} & \text{if } t_1 \text{ then } t_2 \text{ else } t_3 \\
| {} & x \\
| {} & \text{fun } x : T \rightarrow \{t\} \\
| {} & t_1\ t_2 \\
| {} & (t_1, \ldots, t_i) \\
| {} & \text{match } t_1 \{(x_1, \ldots, x_i) \rightarrow t_2\} \\
| {} & \text{let } x = t_1 \text{ in } t_2
\end{aligned}
$$

Values

$$
\begin{aligned}
v ::= {} & \mathsf{T} \\
| {} & \mathsf{F} \\
| {} & \text{fun } x : T \rightarrow \{t\} \\
| {} & (v_1, \ldots, v_i)
\end{aligned}
$$

Types

$$
\begin{aligned}
T ::= {} & \text{Bool} \\
| {} & (T_1, \ldots, T_i) \\
| {} & T_1 \rightarrow T_2
\end{aligned}
$$

Example: Tuple

(T, F, T, F, F)

```
fun ($p$ : (Bool, Bool, Bool)) → {
        match $p$ {
            $(x, y, z)$ → if $x$
                          then if $y$
                                  then $z$
                                  else False
                          else False
        }
}
```

Statics: Bools

$$\frac{\Gamma \vdash t_1 : \mathsf{Bool} \qquad \Gamma \vdash t_2 : T \qquad \Gamma \vdash t_3 : T}{\Gamma \vdash \mathsf{if}\ t_1\ \mathsf{then}\ t_2\ \mathsf{else}\ t_3 : T}\ \text{If}$$

$$\frac{}{\Gamma \vdash \mathsf{T} : \mathsf{Bool}}\ \text{T}$$

$$\frac{}{\Gamma \vdash \mathsf{F} : \mathsf{Bool}}\ \text{F}$$

Statics: Functions

$$\frac{}{\Gamma_1, x : T, \Gamma_2 \vdash x : T}\ \text{Var}$$

$$\frac{\Gamma, x : T_1 \vdash t : T_2}{\Gamma \vdash \mathsf{fun}\, x : T_1 \to \{t\} : T_1 \to T_2}\ \text{Fun}$$

$$\frac{\Gamma \vdash t_1 : T_1 \to T_2 \qquad \Gamma \vdash t_2 : T}{\Gamma \vdash t_1\, t_2 : T_2}\ \text{App}$$

$$\frac{\Gamma \vdash t_1 : T_1 \qquad \Gamma, x : T_1 \vdash t : T_2}{\Gamma \vdash \mathsf{let}\, x = t_1\, \mathsf{in}\, t_2 : T}\ \text{Let}$$

Statics: Tuples

$$\frac{\Gamma \vdash t_1 : T_1 \quad \cdots \quad \Gamma \vdash t_i : T_i}{\Gamma \vdash (t_1, \ldots, t_i) : (T_1, \ldots, T_i)}\ \text{Tuple}$$

$$\frac{\Gamma \vdash t_1 : (T_1, \ldots, T_i) \qquad \Gamma, x_1 : T_1, \ldots, x_i : T_i \vdash t_2 : T}{\Gamma \vdash \mathsf{match}\ t_1 \{(x_1, \ldots, x_i) \rightarrow t_2\} : T}\ \text{Match}$$

Call-by-Value Dynamics: Bools

$$\frac{t_1 \rightsquigarrow t_1'}{\text{if } t_1 \text{ then } t_2 \text{ else } t_3 \rightsquigarrow \text{if } t_1' \text{ then } t_2 \text{ else } t_3}\ \text{If}$$

$$\frac{}{\text{if T then } t_2 \text{ else } t_3 \rightsquigarrow t_2}\ \text{IfT}$$

$$\frac{}{\text{if F then } t_2 \text{ else } t_3 \rightsquigarrow t_3}\ \text{IfF}$$

Call-by-Value Dynamics: Functions

$$\frac{t_1 \rightsquigarrow t_1'}{t_1\, t_2 \rightsquigarrow t_1'\, t_2}\ \text{App1}$$

$$\frac{}{\mathsf{let}\, x = v\, \mathsf{in}\, t \rightsquigarrow [v/x]t}\ \text{Let}\beta$$

$$\frac{t_2 \rightsquigarrow t_2'}{v_1\, t_2 \rightsquigarrow v_1\, t_2'}\ \text{App2}$$

$$\frac{}{(\mathsf{fun}\, x : T \to \{t\})\, v \rightsquigarrow [v/x]t}\ \beta$$

$$\frac{t_1 \rightsquigarrow t_1'}{\mathsf{let}\, x = t_1\, \mathsf{in}\, t_2 \rightsquigarrow \mathsf{let}\, x = t_1'\, \mathsf{in}\, t_2}\ \text{Let}$$

Call-by-Value Dynamics: Tuples

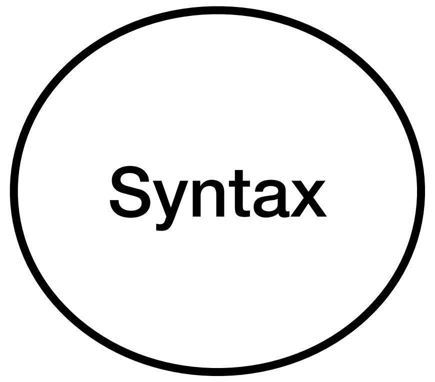
$$\frac{t_{i+1} \rightsquigarrow t'_{i+1}}{(v_1, \ldots, v_i, t_{i+1}, \ldots, t_j) \rightsquigarrow (v_1, \ldots, v_i, t'_{i+1}, \ldots, t_j)}\ \text{Tuple}$$

Call-by-Value Dynamics: Tuples

$$\frac{t_1 \rightsquigarrow t_1'}{\mathsf{match}\, t_1 \{(x_1, \ldots, x_i) \to t_2\} \rightsquigarrow \mathsf{match}\, t_1' \{(x_1, \ldots, x_i) \to t_2\}}\ \text{Match}$$

$$\frac{}{\mathsf{match}\, (v_1, \ldots, v_i) \{(x_1, \ldots, x_i) \to t_2\} \rightsquigarrow [v_1/x_1]\cdots[v_i/x_i]t_2}\ \text{Tuple}\beta$$

Core Design Concepts:



Syntax

Part 4:Records

New Syntactic Forms: Adding Records

Suppose we have a set of labels $\mathscr{L}$

Terms

$$
\begin{aligned}
t ::=\ & \mathsf{T} \\
\mid\ & \mathsf{F} \\
\mid\ & \mathsf{if}\ t_1\ \mathsf{then}\ t_2\ \mathsf{else}\ t_3 \\
\mid\ & x \\
\mid\ & \mathsf{fun}\ x : T \to \{t\} \\
\mid\ & t_1\ t_2 \\
\mid\ & (l_1 = t_1, \ldots, l_i = t_i) \\
\mid\ & t\,.\,l \\
\mid\ & \mathsf{let}\ x = t_1\ \mathsf{in}\ t_2
\end{aligned}
$$

Values

$$
\begin{aligned}
v ::=\ & \mathsf{T} \\
\mid\ & \mathsf{F} \\
\mid\ & \mathsf{fun}\ x : T \to \{t\} \\
\mid\ & (l_1 = v_1, \ldots, l_i = v_i)
\end{aligned}
$$

Types

$$
\begin{aligned}
T ::=\ & \mathsf{Bool} \\
\mid\ & (l_1 : T_1, \ldots, l_i : T_i) \\
\mid\ & T_1 \to T_2
\end{aligned}
$$

Example: Records

$(x = 2, y = 5) : (x : \mathsf{Int}, y : \mathsf{Int})$

$(\text{desc} = \text{"brake rotor"}, \text{partno} = 3947, \text{cost} = 250) : (\text{desc} : \mathsf{String}, \text{partno} : \mathsf{Int}, \text{cost} : \mathsf{Float})$

Statics: Bools

$$\frac{\Gamma \vdash t_1 : \mathsf{Bool} \qquad \Gamma \vdash t_2 : T \qquad \Gamma \vdash t_3 : T}{\Gamma \vdash \mathsf{if}\ t_1\ \mathsf{then}\ t_2\ \mathsf{else}\ t_3 : T}\ \text{If}$$

$$\frac{}{\Gamma \vdash \mathsf{T} : \mathsf{Bool}}\ \text{T}$$

$$\frac{}{\Gamma \vdash \mathsf{F} : \mathsf{Bool}}\ \text{F}$$

Statics: Functions

$$\frac{}{\Gamma_1, x : T, \Gamma_2 \vdash x : T}\ \textsf{Var}$$

$$\frac{\Gamma, x : T_1 \vdash t : T_2}{\Gamma \vdash \textsf{fun}\, x : T_1 \to \{t\} : T_1 \to T_2}\ \textsf{Fun}$$

$$\frac{\Gamma \vdash t_1 : T_1 \to T_2 \quad \Gamma \vdash t_2 : T}{\Gamma \vdash t_1\, t_2 : T_2}\ \textsf{App}$$

$$\frac{\Gamma \vdash t_1 : T_1 \qquad \Gamma, x : T_1 \vdash t : T_2}{\Gamma \vdash \textsf{let}\, x = t_1\, \textsf{in}\, t_2 : T}\ \textsf{Let}$$

Statics: Records

$$\frac{\Gamma \vdash t_1 : T_1 \quad \cdots \quad \Gamma \vdash t_i : T_i}{\Gamma \vdash (l_1 = t_1, \ldots, l_i = t_i) : (l_1 : T_1, \ldots, l_i : T_i)}\ \text{Record}$$

$$\frac{\Gamma \vdash t : (l_1 : T_1, \ldots, l_i : T_i)}{\Gamma \vdash t\,.\,l_i : T_i}\ \text{Proj}$$

Call-by-Value Dynamics: Bools

$$\frac{t_1 \rightsquigarrow t_1'}{\text{if } t_1 \text{ then } t_2 \text{ else } t_3 \rightsquigarrow \text{if } t_1' \text{ then } t_2 \text{ else } t_3}\ \text{If}$$

$$\frac{}{\text{if T then } t_2 \text{ else } t_3 \rightsquigarrow t_2}\ \text{IfT}$$

$$\frac{}{\text{if F then } t_2 \text{ else } t_3 \rightsquigarrow t_3}\ \text{IfF}$$

Call-by-Value Dynamics: Functions

$$\frac{t_1 \rightsquigarrow t_1'}{t_1\,t_2 \rightsquigarrow t_1'\,t_2}\ \text{App1}$$

$$\frac{}{\mathsf{let}\,x = v\,\mathsf{in}\,t \rightsquigarrow [v/x]t}\ \text{Let}\beta$$

$$\frac{t_2 \rightsquigarrow t_2'}{v_1\,t_2 \rightsquigarrow v_1\,t_2'}\ \text{App2}$$

$$\frac{}{(\mathsf{fun}\,x : T \rightarrow \{t\})\,v \rightsquigarrow [v/x]t}\ \beta$$

$$\frac{t_1 \rightsquigarrow t_1'}{\mathsf{let}\,x = t_1\,\mathsf{in}\,t_2 \rightsquigarrow \mathsf{let}\,x = t_1'\,\mathsf{in}\,t_2}\ \text{Let}$$

Call-by-Value Dynamics: Records

$$\frac{t_{i+1} \rightsquigarrow t'_{i+1}}{(l_1 = v_1, \ldots, l_i = v_i, l_{i+1} = t_{i+1}, \ldots, l_j = t_j) \rightsquigarrow (l_1 = v_1, \ldots, l_i = v_i, l_{i+1} = t'_{i+1}, \ldots, l_j = t_j)}\ \text{Record}$$

Call-by-Value Dynamics: Records

$$\frac{t \rightsquigarrow t'}{t\,.\,l_i \rightsquigarrow t'\,.\,l_i}\ \text{Proj}$$

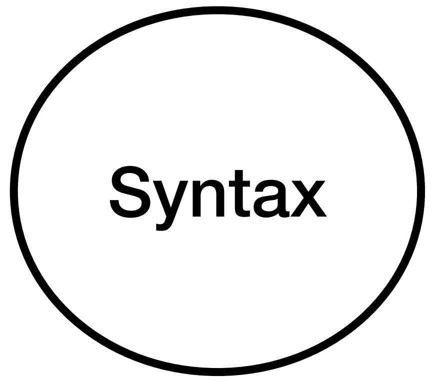
$$\frac{}{(l_1 = v_1, \ldots, l_i = v_i)\,.\,l_j \rightsquigarrow v_j}\ \text{Record}\beta$$

Core Design Concepts:

Syntax

Part 5: Mutable References

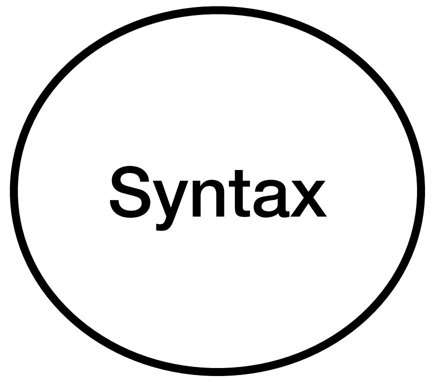
Core Design Concepts:



Syntax

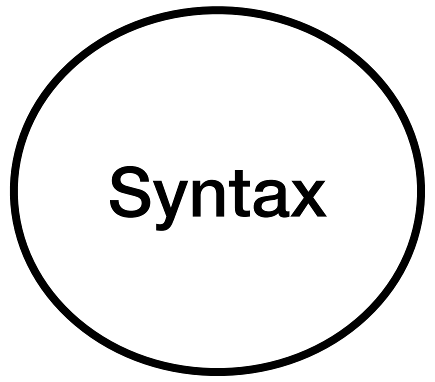
Part 6: Subtyping

Core Design Concepts:



Part 7: Imperative Objects

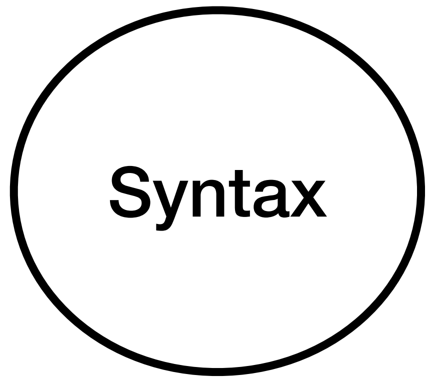
Core Design Concepts:



Part 8: OOP in OCaml

What is OCaml?

Core Design Concepts:

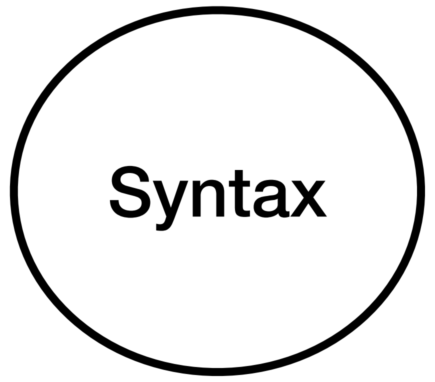


Syntax

An object oriented, imperative, functional programming language.

What is OCaml?

Core Design Concepts:

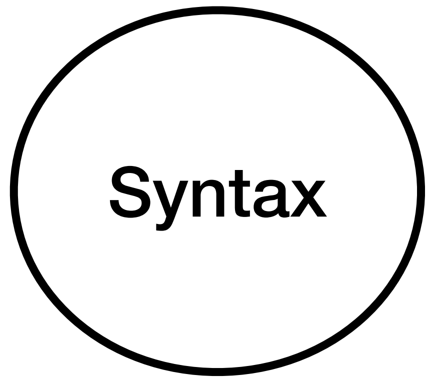


An object oriented, imperative, functional programming language.

OCaml mixes all of these paradigms together.

What is OCaml?

Core Design Concepts:



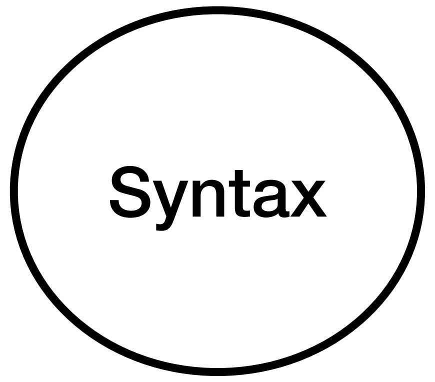
Syntax

An object oriented, imperative, functional programming language.

OCaml mixes all of these paradigms together.

What is OCaml?

Core Design Concepts:



Syntax

An object oriented, imperative, functional programming language.

OCaml mixes all of these paradigms together.

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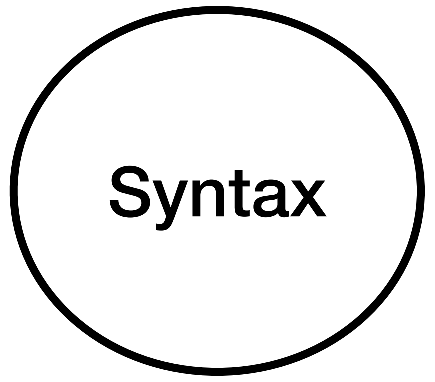

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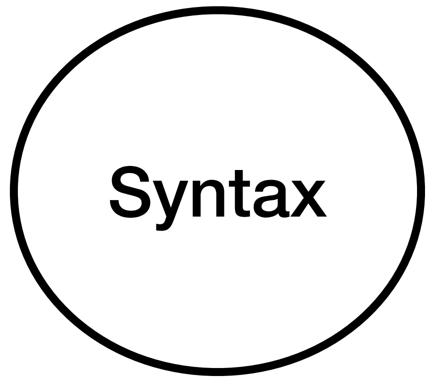

Syntax

An object oriented, imperative, functional programming language.

OCaml mixes all of these paradigms together.

Class Definitions

Core Design Concepts:

Syntax

```
class name = object (self) … end
```

Class Definitions

Core Design Concepts:

Syntax

```
class stack_of_ints =
  object (self)
    val mutable the_list = ([] : int list)
    …
  end;;
```

Class Definitions

Core Design Concepts: Syntax

```
class stack_of_ints =
  object (self)
    val mutable the_list = ([] : int list)
    method push x = …
    method pop = …
    method peek = …
    method size = …
  end;;
```

Class Definitions

Core Design Concepts:

Syntax

```
class stack_of_ints =
  object (self)
    val mutable the_list = ([] : int list)
    method push x = the_list <- Cons(x, the_list)
    method pop = …
    method peek = …
    method size = …
  end;;
```

Class Definitions

Core Design Concepts:

Syntax

```
class stack_of_ints =
  object (self)
    val mutable the_list = ([] : int list)
    method pop =
      let result = head the_list in
      the_list <- tail the_list;
      result
    method push x = …
    method peek = …
    method size = …
  end;;
```

Class Definitions

Core Design Concepts:

Syntax

```
class stack_of_ints =
  object (self)
    val mutable the_list = ([] : int list)
    method push x = …
    method pop = …
    method peek = head the_list
    method size = …
  end;;
```

Class Definitions

Core Design Concepts:

Syntax

```
class stack_of_ints =
  object (self)
    val mutable the_list = ([] : int list)
    method push x = …
    method pop = …
    method peek = …
    method size = length the_list
  end;;
```

Class Definitions

Core Design Concepts:

Syntax

```
class stack_of_ints =
  object (self) …
end;;
class stack_of_ints :
  object
    val mutable the_list : int list
    method peek : int
    method pop : int
    method push : int -> unit
    method size : int
  end
```

Accessing fields and methods

Core Design Concepts:

Syntax

```
# let s = new stack_of_ints;;
val s : stack_of_ints = <obj>
```

Accessing fields and methods

Core Design Concepts:

Syntax

```
s#fieldName

s#methodName
```

Accessing fields and methods

Core Design Concepts:

Syntax

```
# for i = 1 to 10 do
    s#push i
  done;;
- : unit = ()
# while s#size > 0 do
    Printf.printf "Popped %d off the stack.\n" s#pop
  done;;
…
Popped 10 off the stack.
Popped 9 off the stack.
Popped 8 off the stack.
- : unit = ()
```