State

Side-effect!

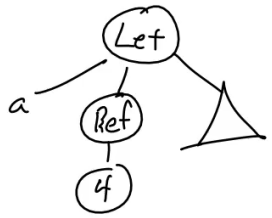
$e ::= \overset{Fb}{\sim\sim} \mid Ref\ e \mid !e \mid e := e$

$v ::= \overset{Fb}{\sim\sim} \mid c$

$c ::= $ (infinitely many cell names)

$S ::= \{ c \mapsto v, \ldots \}$

$\langle S, e \rangle \Rightarrow \langle S, v \rangle$



Let a = Ref 4 In Let b = a := 5 In !a + 1

e_1

$$\frac{\dfrac{}{\langle \emptyset, 4 \rangle \Rightarrow \langle \emptyset, 4 \rangle}}{\dfrac{\langle \emptyset, Ref\ 4 \rangle \Rightarrow \langle \{c_0 \mapsto 4\}, c_0 \rangle \qquad \langle \{c_0 \mapsto 4\}, Let\ b = c_0 := 5\ In\ !c_0 + 1 \rangle \Rightarrow \langle \{c_0 \mapsto 5\}, 6 \rangle}{\langle \emptyset, e_1 \rangle \Rightarrow \langle \{c_0 \mapsto 5\}, 6 \rangle}}$$

Exceptions

```
try ...
    raise (Foo 4)
with
| Foo n -> ...
```

```
let f ... =
    raise (Foo 4)
;;
```

```
try {
  ...
  throw runtime_error("argh!");
} catch (runtime_error& e) {
  ...
}
```

```
void remove(K key) {
  ...
  ...
  throw runtime_error "argh!");
}
```

FbX

$e ::= \overbrace{\ldots}^{Fb} \mid \#\ell\ e \mid \text{Raise}\ e \mid \text{Try}\ e\ \text{With}\ \#\ell\ x \to e$

$v ::= \overbrace{\ldots}^{Fb} \mid \#\ell\ v \mid \underbrace{\text{Raised}\ v}_{\text{no concrete syntax}}$

$$\#A\ 5 \Longrightarrow \#A\ 5$$

$$\text{Raise}\ (\#A\ 5) \Longrightarrow \text{Raised}\ (\#A\ 5)$$

$$1 + \text{Raise}\ (\#A\ 5) \Longrightarrow \text{Raised}\ (\#A\ 5)$$

$$\text{Raise}\ (\#B\ 0) + \text{Raise}\ (\#A\ 5) \Longrightarrow \text{Raised}\ (\#B\ 0)$$

Exc. Values $\dfrac{e \Rightarrow v}{\#\ell\ e \Rightarrow \#\ell\ v}$

Raise $\dfrac{e \Rightarrow \#\ell\ v}{\text{Raise}\ e \Rightarrow \text{Raised}\ (\#\ell\ v)}$

Don't say "$v \neq \text{Raised}\ v'$"

$\forall v'.\ v \neq \text{Raised}\ v'$

$$+\begin{cases} \text{Raise + Left} & \dfrac{e_1 \Rightarrow \text{Raised}\ (\#\ell\ v)}{e_1 + e_2 \Rightarrow \text{Raised}\ (\#\ell\ v)} \\ \text{Raise + Right} & \dfrac{e_1 \Rightarrow v \quad \text{Raised}\ v' \quad e_2 \Rightarrow \text{Raised}\ (\#\ell\ v)}{e_1 + e_2 \Rightarrow \text{Raised}\ (\#\ell\ v)} \end{cases}$$

(v not of form)

WE NEED A LOT OF THESE

Try Success $\dfrac{e_1 \Rightarrow v \qquad v \text{ not of form Raised } v'}{\text{Try } e_1 \text{ With } \#\ell\ x \to e_2 \Rightarrow v}$

Try Fail $\dfrac{e_1 \Rightarrow \text{Raised}\ (\#\ell\ v) \qquad e_2[v/x] \Rightarrow v'}{\text{Try } e_1 \text{ With } \#\ell\ x \to e_2 \Rightarrow v'}$

Raise Try $\dfrac{e_1 \Rightarrow \text{Raised}\ (\#\ell'\ v)}{\text{Try } e_1 \text{ With } \#\ell\ x \to e_2 \Rightarrow \text{Raised}\ (\#\ell'\ v)}$