# Grammar

## Base Type

$\tau ::= \sigma \mid r$

$\sigma ::= \mathit{float} \mid \sigma \times \sigma \mid \eta \cdot \sigma$

## Natural Numbers

$\eta ::= 0 \mid 1 \mid \ldots$

## Range

$r ::= \eta..\eta$

# Term

$t ::= \text{fl} \mid \eta \mid p \mid \text{for } i : r \text{ in } t \mid \text{let } x = t \text{ in } t \mid (t, t)$

- $i$ and $x$ are identifiers.

## Literal

$\text{fl} ::= 0.0 \mid -4.21 \mid 523.215 \mid \ldots$

## Place Expression

$p ::= x \mid p[t] \mid p.\text{fst} \mid p.\text{snd}$

# Environment

## Type Environment

$\Gamma ::= \bullet \mid \Gamma, (x : \tau)$

# Typing Rules

$$\frac{x : \sigma \in \Gamma}{\Gamma \vdash x : \sigma}\ \text{T-VAR}$$

$$\frac{\Gamma \vdash t : \sigma \quad \Gamma, (x : \sigma) \vdash t_{\text{body}} : \sigma_{\text{body}}}{\Gamma \vdash \text{let } x = t \text{ in } t_{\text{body}} : \sigma_{\text{body}}}\ \text{T-LET}$$

$$\frac{r : \text{ok} \quad \Gamma, (i : r) \vdash t_{\text{body}} : \sigma}{\Gamma \vdash \text{for } i : r \text{ in } t_{\text{body}} : r \cdot \sigma}\ \text{T-FOR}$$

$$\frac{\Gamma \vdash t[\eta..(\eta + 1)]}{\Gamma \vdash t[\eta] : \sigma}\ \text{T-INDEX-NAT}$$

$$\frac{\Gamma \vdash t : \eta_t \cdot \sigma \quad \Gamma \vdash t_{\text{index}} : \eta_l..\eta_r \quad \eta_r \leq \eta_t}{\Gamma \vdash t[t_{\text{index}}] : \sigma}\ \text{T-INDEX-RANGE}$$

$$\frac{\Gamma \vdash t : \sigma_1 \times \sigma_2}{\Gamma \vdash t.\text{fst} : \sigma_1}\ \text{T-FST}$$

$$\frac{\Gamma \vdash t : \sigma_1 \times \sigma_2}{\Gamma \vdash t.\text{snd} : \sigma_2}\ \text{T-SND}$$

## Well-formedness rules

$$\frac{\eta_1 \leq \eta_2}{\eta_1..\eta_2 : \mathrm{ok}}\ \text{W-RANGE-ONE}$$

# Examples

## For expression

```
for i: (0..5) in
  for j: (0..6) in
    for k: (0..7) in
      4.2
```

This results in a value of type $5 \cdot 6 \cdot 7 \cdot float$

```
for i : 0..5 in
  for j: 0..10 in
    1.2
```

This results in a value of type $5 \cdot 10 \cdot float$

## Indexing by a value of type range

```
for i: 0..5 in
  a[0][i]
```

This is equivalent to: `a[0][0:5]`

## Slicing

```
for i: 0..10 in
  for j: 0..5 in
    a[i][j]
```

This is of type $10 \cdot 5 \cdot \sigma$ and equivalent to `a[0..10][0..5]` where $\sigma$ is the type of $a[0][0]$

## let in

```
let arr =
  for i: 0..5 in
    for j : 0..5 in
      3.14159
in
for i: 0..2 in
  for j: 0..1 in
    arr[i][j]
```

This is of type $2 \cdot 1 \cdot float$

## let in, for, and tuple

### tuple

```
let arr_1 =
  for i: 0..5 in
    for j: 0..5 in
      3.14159 in
let arr_2 =
  for i: 2..4 in
    for j: 1..3 in
      arr_1[i][j] in
(arr_1, arr_2)
```

This is of type $(5 \cdot 5 \cdot float) \times (2 \cdot 2 \cdot float)$

### Nested tuple/array

```
let tup = (3.14159, for i : 0..5 in 6.25) in
  for i : 0..10 in
    tup
```

This is of type $10 \cdot (float \times (5 \cdot float))$