Intermediate Representation

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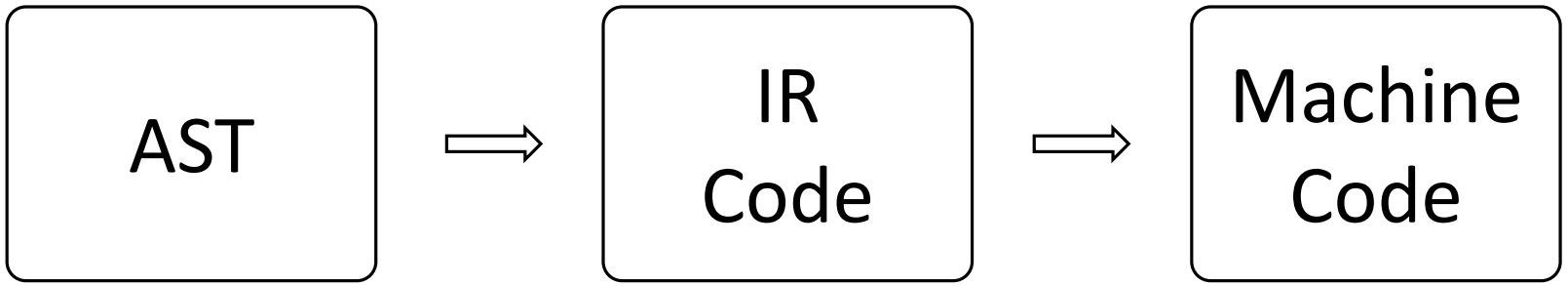
Intermediate Representation

- Generic representation of instructions
  - Allows **language** and **machine** independent optimizations
  - Not executable



IR Language

- Temporary variables (IR registers)
  - t1, t2, … (unlimited)
- Instructions
  - assignments, add, sub, call, return, …
- Labels
  - label_1:

IR Instructions

Constant assignment:

- **<register> = <constant>**
  - t1 = 7

IR Instructions

Read from memory:

- **<register> = <variable_name>**
  - t1 = x

Write to memory:

- **<variable_name> = <register>**
  - y = t2

IR Instructions

Arithmetic operations:

- **<register> = op <register> <register> …**
  - t4 = add t1 t2
  - t0 = sub t0 t1

IR Instructions

Branches:

- **br <label>**
  - br some_label
- **beq <register> [<constant> | <register>] <label>**
  - beq t1 0 label_1
  - beq t2 t3 label_7

IR Instructions

Functions:

- **call <function_name> <args>**
  - call bar
  - call foo t1 t2
- **<register> = call <function_name> <args>**
  - t8 = call foo t7
- **return <register>**
  - return t3

IR Instructions

Arrays:

- **<register> = new_array <register>**
  - t0 = new_array t1
- **<register> = array_access <register> <register>**
  - t0 = array_access t1 t2
- **array_set <register> <register> <register>**
  - array_set t0 t1 t2

IR Instructions

Classes:

- **<register> = new_class <type_name>**
  - t0 = new_class Base
- **<register> = field_access <register> <field_name>**
  - t0 = field_access t1 name
- **field_set <register> <field_name> <register>**
  - field_set t0 name t2
- **virtual_call <register> <method_name> <args>**
  - virtual_call t1 foo
- **<register> = virtual_call <register> <method_name> <args>**
  - t0 = virtual_call t1 foo t20, t21

IR Example

```
int foo(int x, int y) {
  int z = x + y;
  int w = z + 1;
  return w;
}
```

```
t1 = x
t2 = y
t3 = add t1, t2
z = t3
t4 = z
t5 = 1
t6 = add t4, t5
w = t6
t7 = w
return t7
```

Translating AST to IR

- Input: **AST**
- Output: **List of IR instructions**
- Done using **AST visitor**

Translating Expressions

Basic algorithm:

$visit(node)$:

$instlist_1, t_1 = visit(node.child_1)$

…

$instlist_n, t_n = visit(node.child_n)$

$instlist, t_{new} = assemble(instlist_1, \dots, instlist_n, t_1, \dots, t_n)$

$return\ instlist, t_{new}$

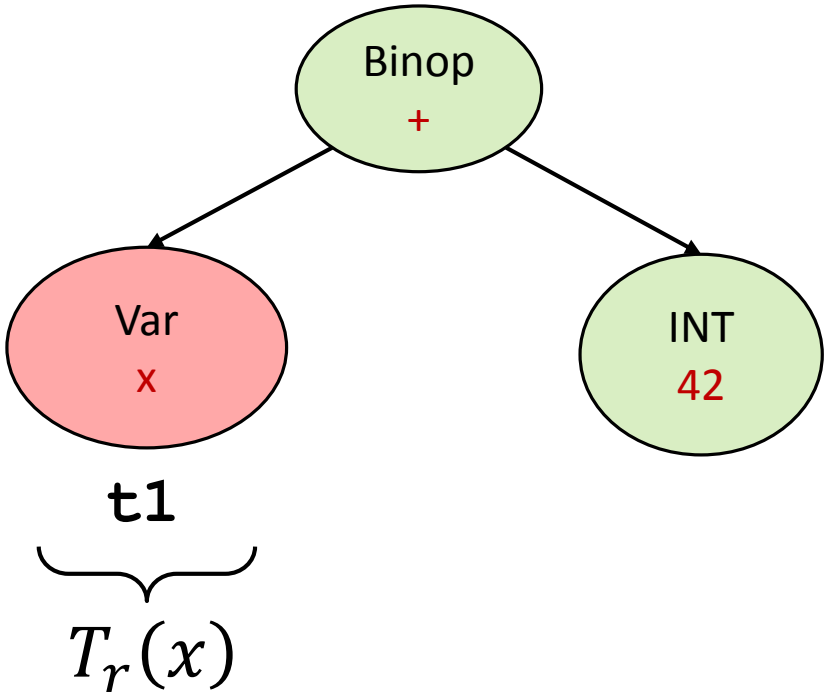
Translating Expressions

For an AST node e we define:

- $T_c(e)$
  - The generated instructions (code)
- $T_r(e)$
  - The register holding the result of the computation

Translating Expressions

For x + 42:

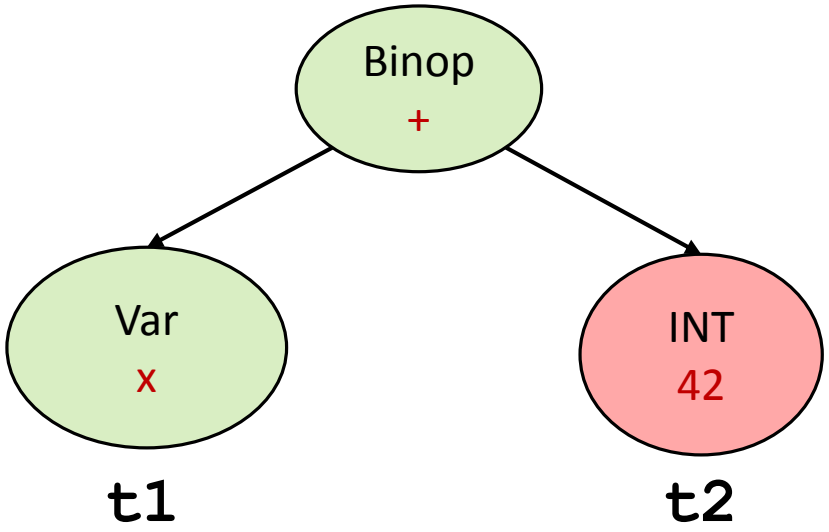


`t1 = x`

$T_c(x)$

Translating Expressions

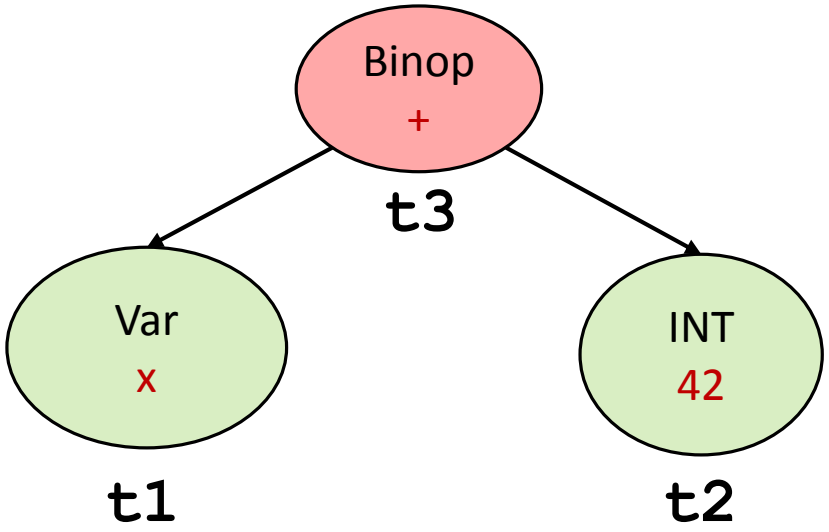
For x + 42:




```
t1 = x
t2 = 42
```

Translating Expressions

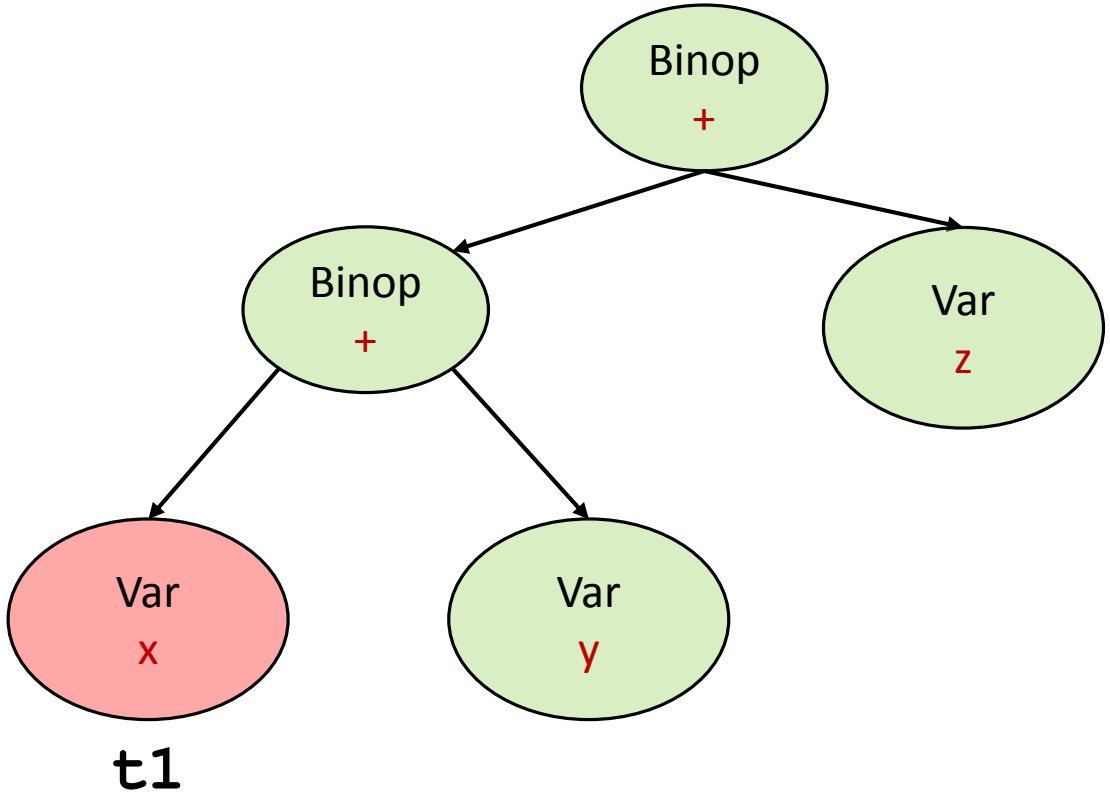
For x + 42:




```
t1 = x
t2 = 42
t3 = add t1, t2
```

Translating Expressions

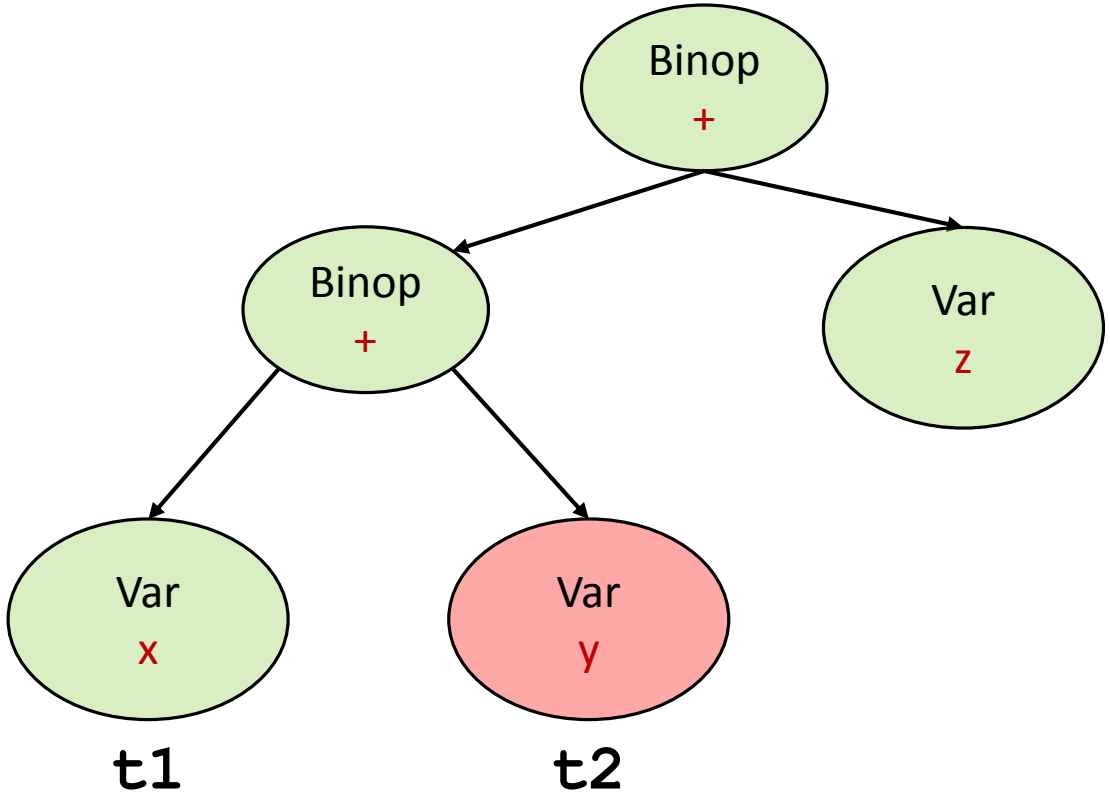
For x + y + z:




```
t1 = x
```

Translating Expressions

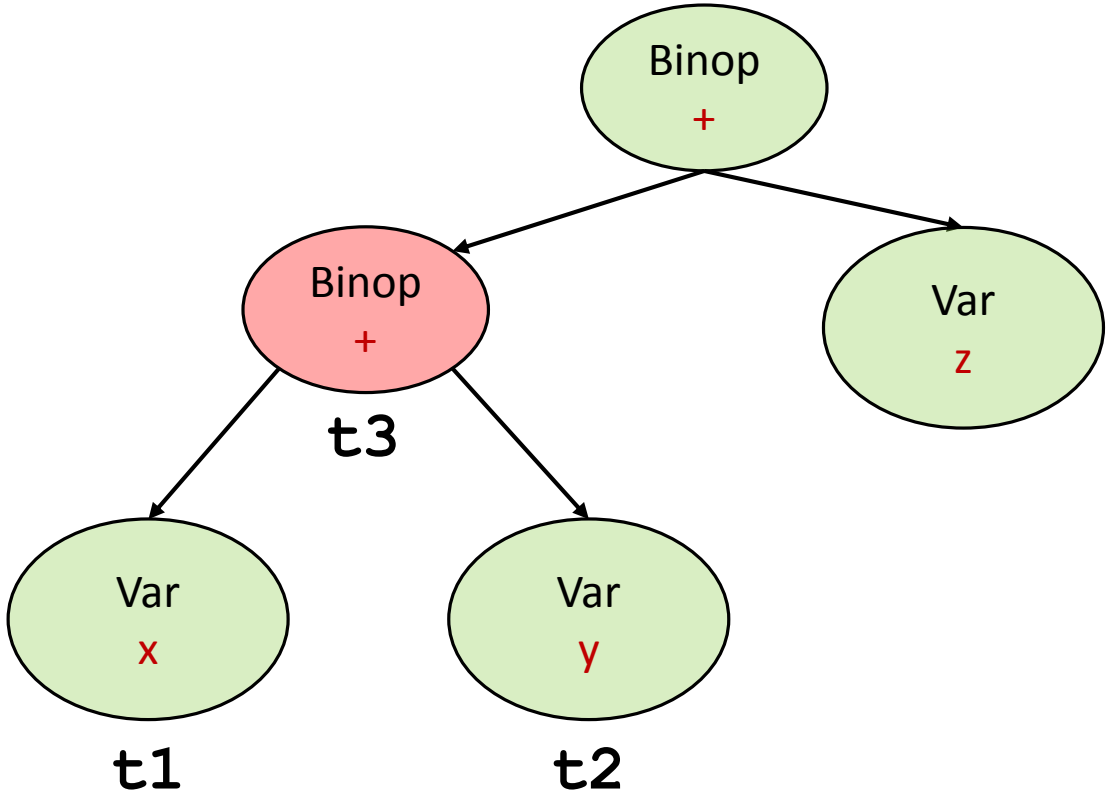
For x + y + z:




```
t1 = x
t2 = y
```

Translating Expressions

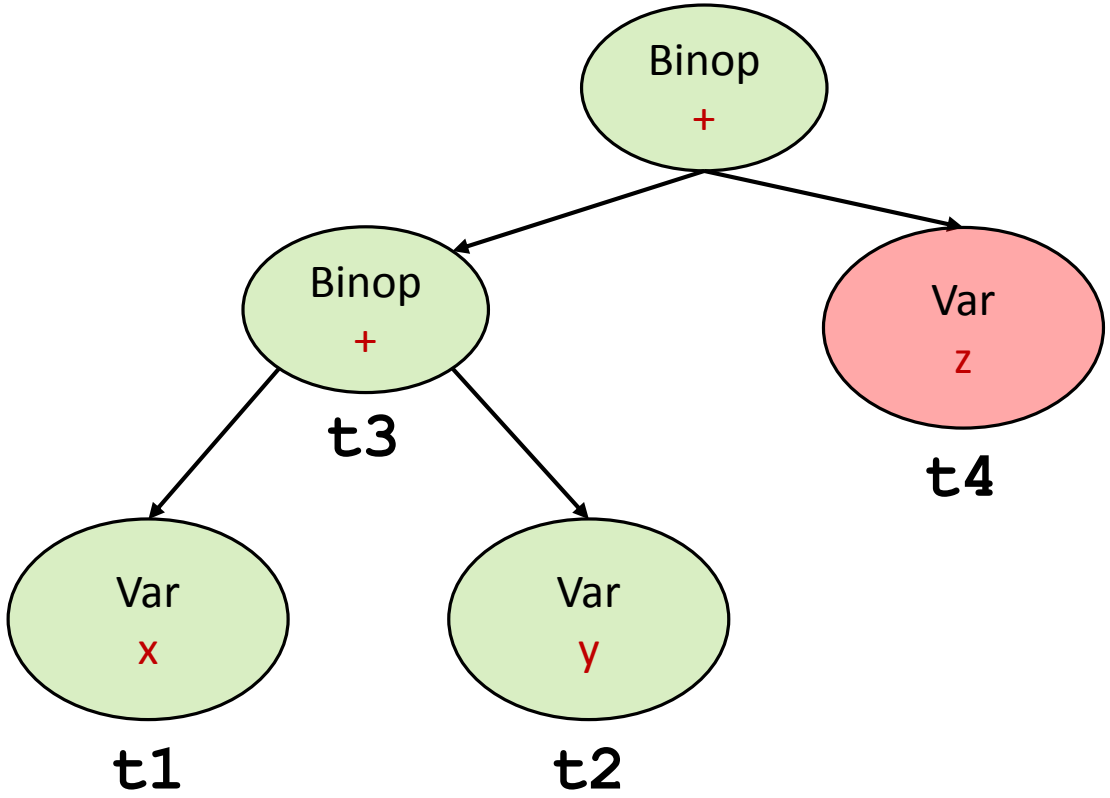
For x + y + z:




```
t1 = x
t2 = y
t3 = add t1, t2
```

Translating Expressions

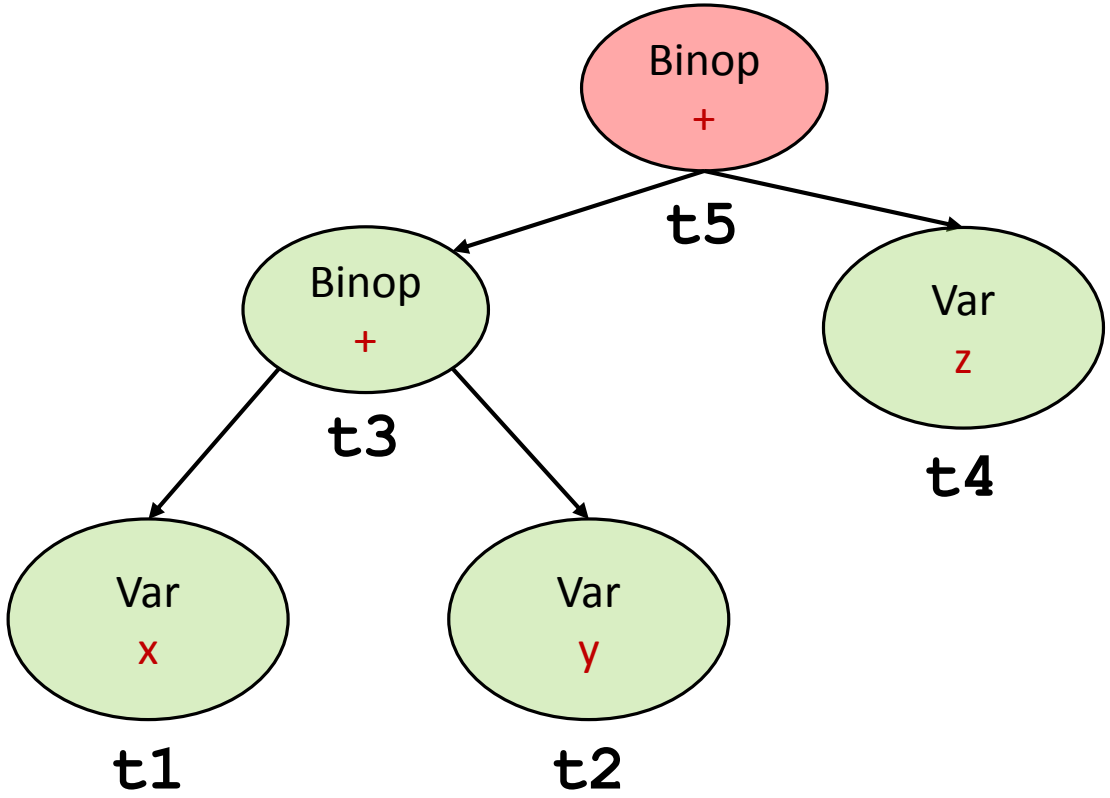
For x + y + z:




```
t1 = x
t2 = y
t3 = add t1, t2
t4 = z
```

Translating Expressions

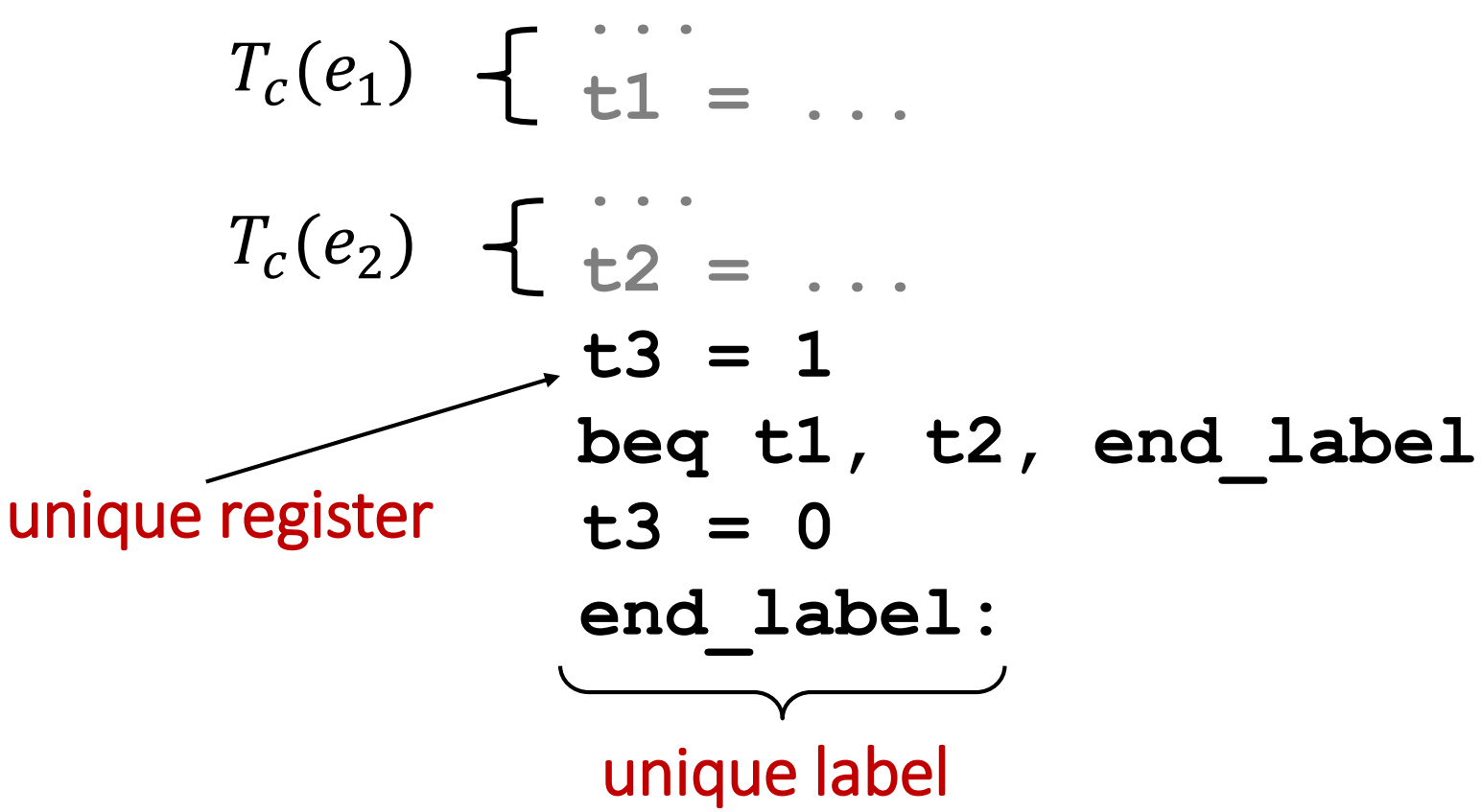
For x + y + z:




```
t1 = x
t2 = y
t3 = add t1, t2
t4 = z
t5 = add t3, t4
```

Translating Expressions

For $e_1 == e_2$:



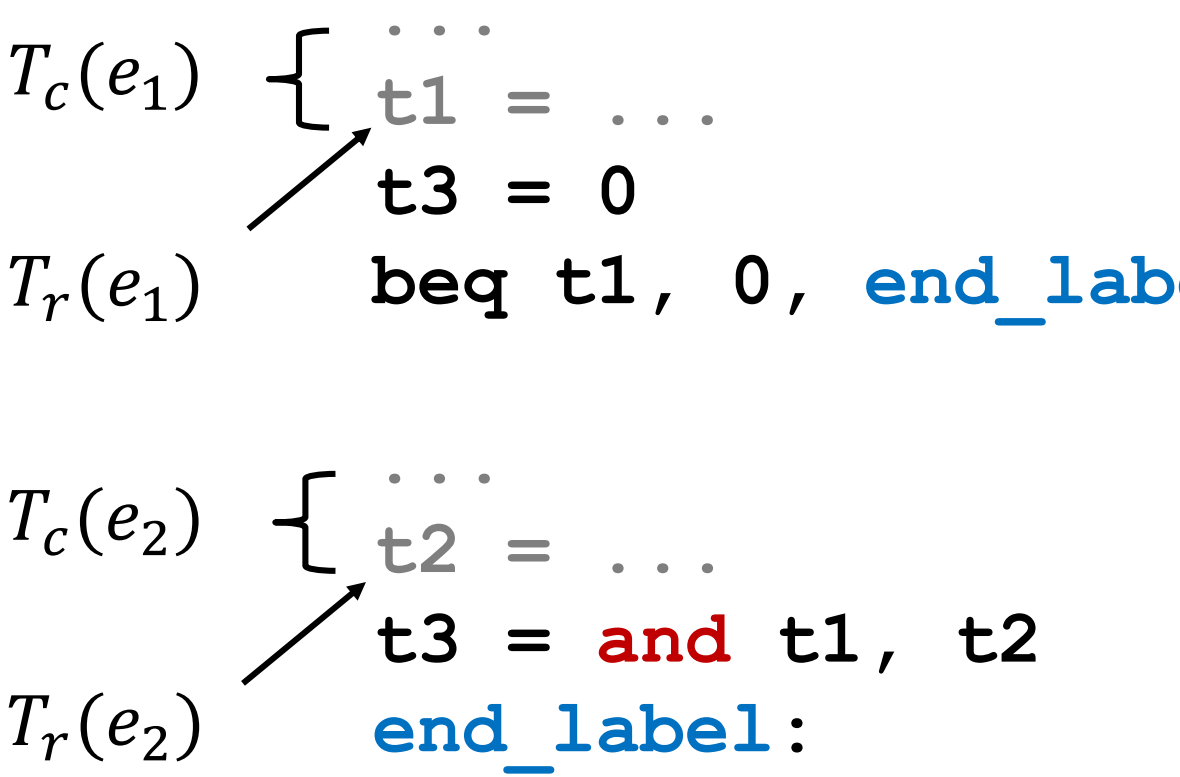
Translating Expressions

For `a == b + 1`:

```
t1 = a
t2 = b
t3 = 1
t4 = add t2, t3
t5 = 1
beq t1, t4, end_label
t5 = 0
end_label:
```

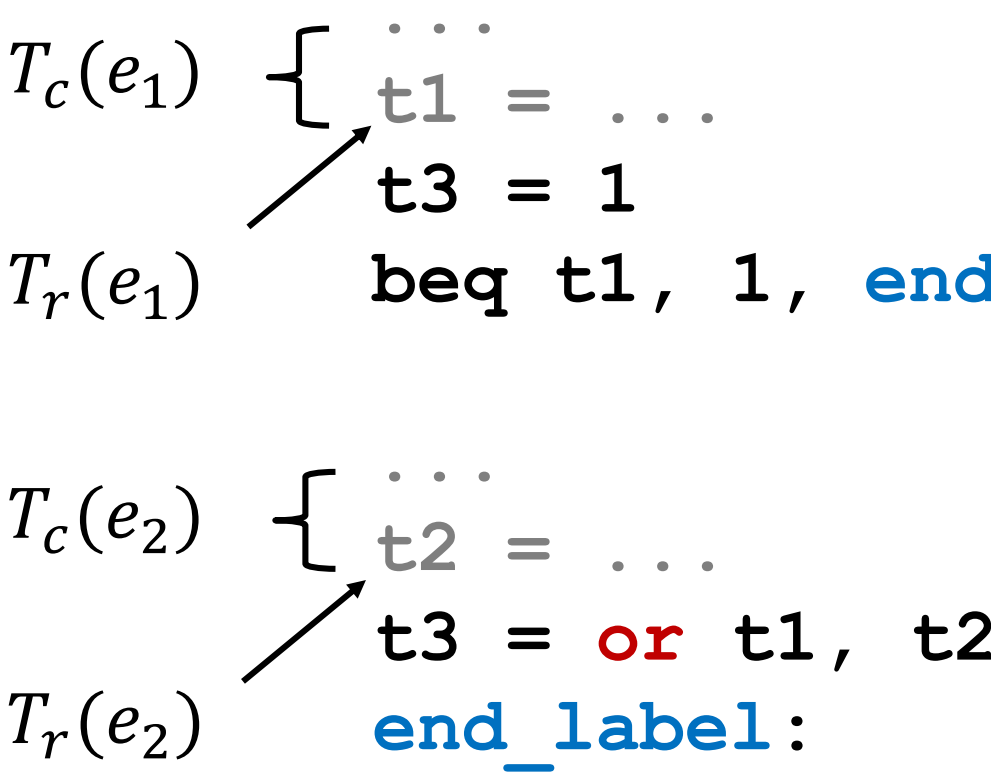
Translating Expressions

For e_1 *and* e_2:



Translating Expressions

For e_1 *or* e_2:



Translating Statements

For $f(e_1, e_2, \ldots)$: *(as rvalue)*

$T_c(e_1)$ { ...
t1 = ...

$T_c(e_2)$ { ...
t2 = ...

...
t3 = call f, t1, t2, ...

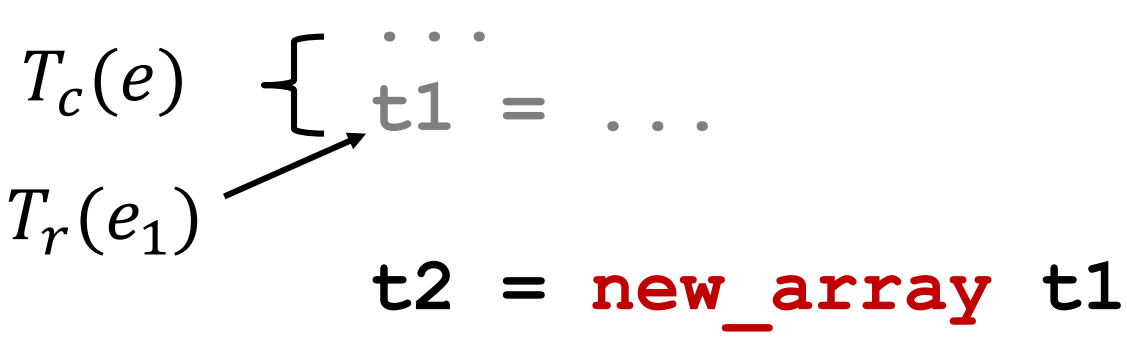
Translating Statements

For func(2, x + 1):

```
t1 = 2
t2 = x
t3 = 1
t4 = add t2, t3
t5 = call func, t1, t4
```

Translating Expressions

For $new\ type[e]$:



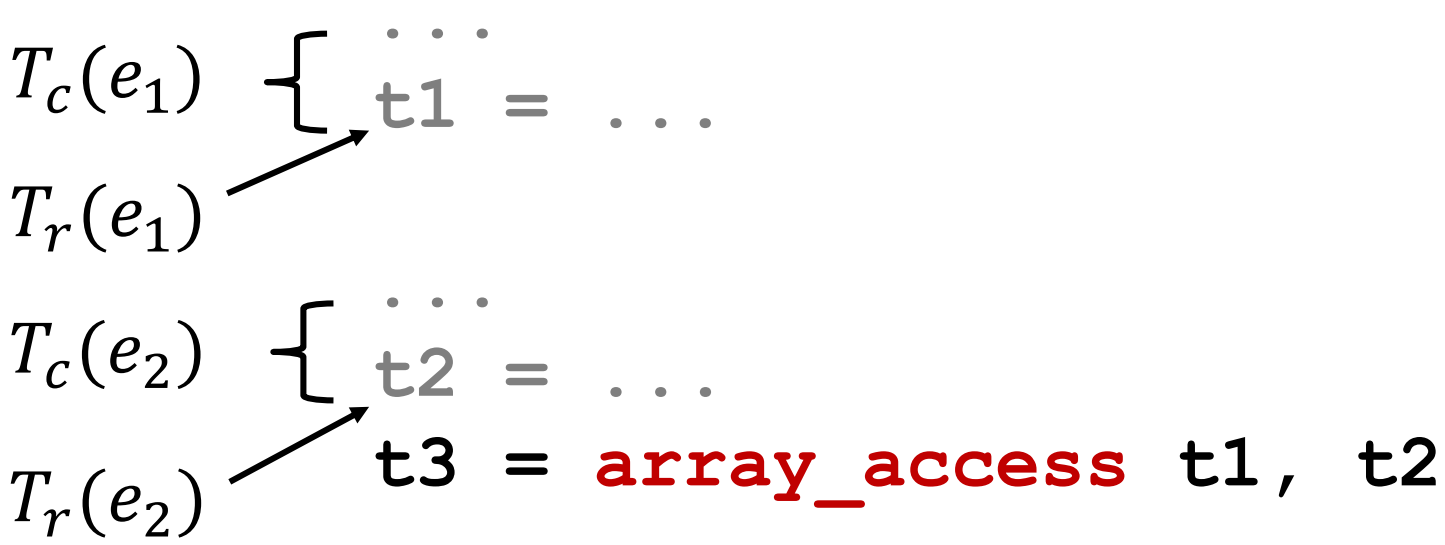
Translating Expressions

For new int[k+1]:

```
t1 = k
t2 = 1
t3 = add t1, t2
t4 = new_array t3
```

Translating Expressions

For $e_1[e_2]$:



Translating Expressions

For x[z+1]:

```
t1 = x
t2 = z
t3 = 1
t4 = add t2, t3
t5 = array_access t1, t4
```

Translating Expressions

For *new type*:

```
t1 = new_class type
```

Translating Expressions

For new Point:

```
t1 = new_class Point
```

Translating Expressions

For $e.f$:

Translating Expressions

For x[3].foo:

```
t1 = x
t2 = 3
t3 = array_access t1, t2
t4 = field_access t3, foo
```

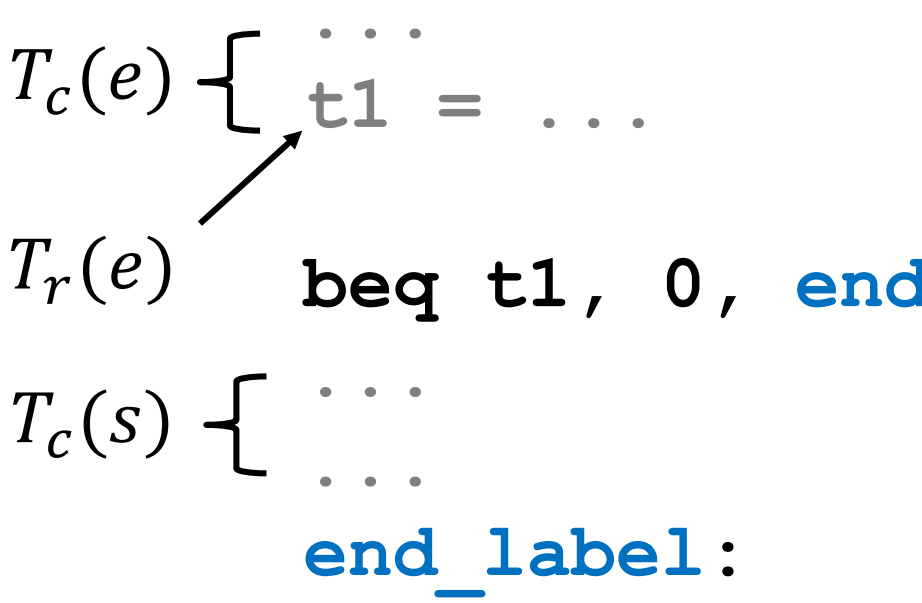
Translating Basic Block

For $s_1; s_2; \ldots$:

$$T_c(s_1)$$
$$T_c(s_2)$$
$$\ldots$$

Translating Statements

For $if\ (e)\ \{s\}$:



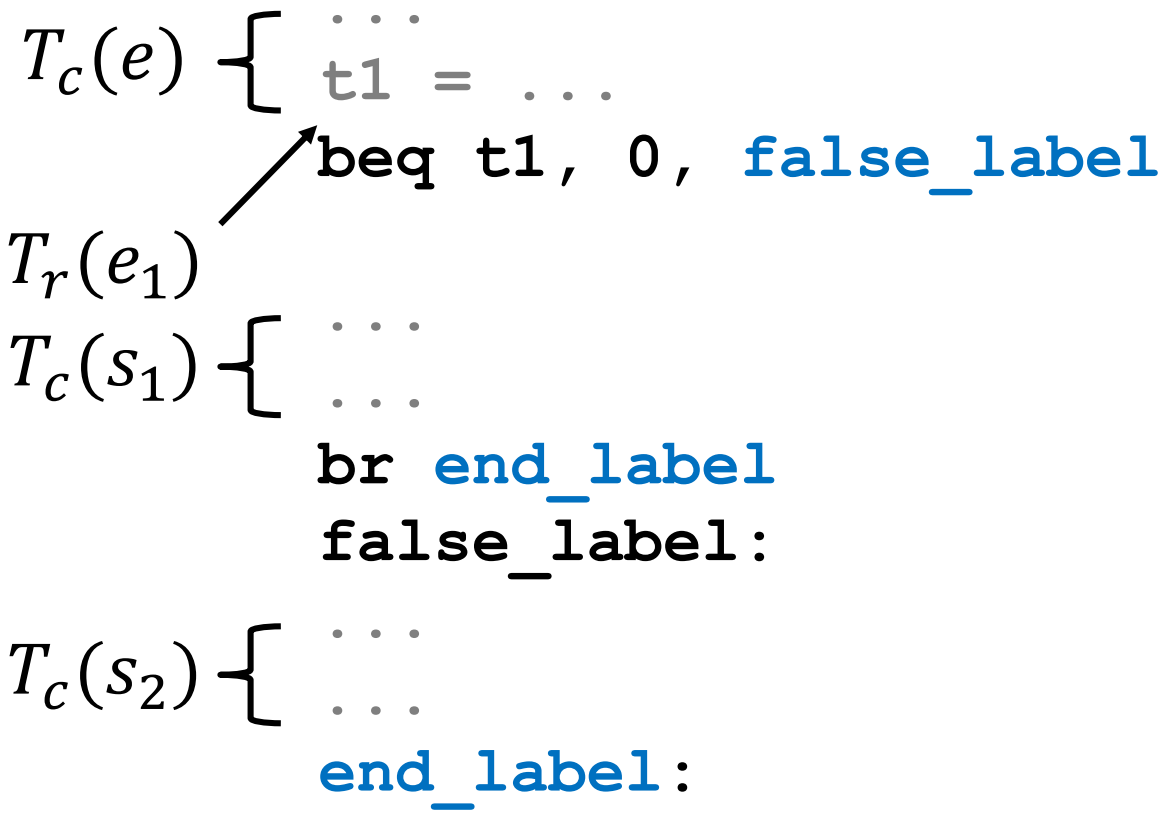
Translating Statements

For if (x * y) { z = 0; }:

```
t1 = x
t2 = y
t3 = mul t1, t2
beq t3, 0, end_label
t4 = 0
z = t4
end_label:
```

Translating Statements

For $if\ (e)\ \{s_1\}\ else\ \{s_2\}$:



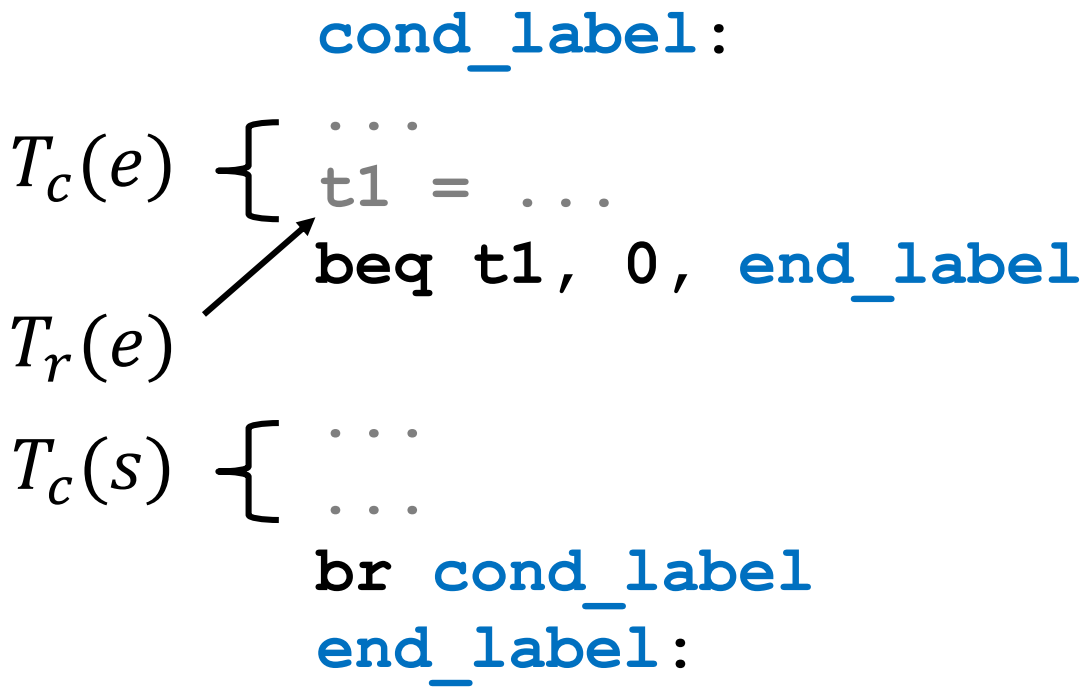
Translating Statements

For if (w) { z = 0; } else { z = 100; }:

```
t1 = w
beq t1, 0, false_label
t2 = 0
z = t2
br end_label
false_label:
t3 = 100
z = t3
end_label:
```

Translating Statements

For $while\ (e)\ \{s\}$:



Translating Statements

For while (z / x) { }:

```
cond_label:
t1 = z
t2 = x
t3 = div t1, t2
beq t3, 0, end_label
br cond_label
end_label:
```

Translating Statements

For $f(e_1, e_2, \dots)$:

$T_c(e_1)$ { ...
t1 = ...

$T_c(e_2)$ { ...
t2 = ...

...
call f, t1, t2, ...

Translating Statements

For func(2, x + 1):

```
t1 = 2
t2 = x
t3 = 1
t4 = add t2, t3
call func, t1, t4
```

Translating Statements

For $return\ e$:

$T_c(e)$ {

```
...
t1 = ...
return t1
```

Translating Statements

For return w * 3:

```
t1 = w
t2 = 3
t3 = mul t1, t2
return t3
```

Translating Statements

For $e_1[e_2] = e_3$:

$T_c(e_1)$ {
```
...
t1
```
$T_c(e_2)$ {
```
...
t2 = ...
```
$T_c(e_3)$ {
```
...
t3 = ...
array_set t1, t2, t3
```

Translating Statements

For arr[0] = x+1:

```
t1 = arr
t2 = 0
t3 = x
t4 = 1
t5 = add t3, t4
array_set t1, t2, t5
```

Translating Statements

For $o.f = e$:

$T_c(o)$ { ...
t1

$T_c(e)$ { ...
t2 = ...

```
field_set t1, f, t2
```

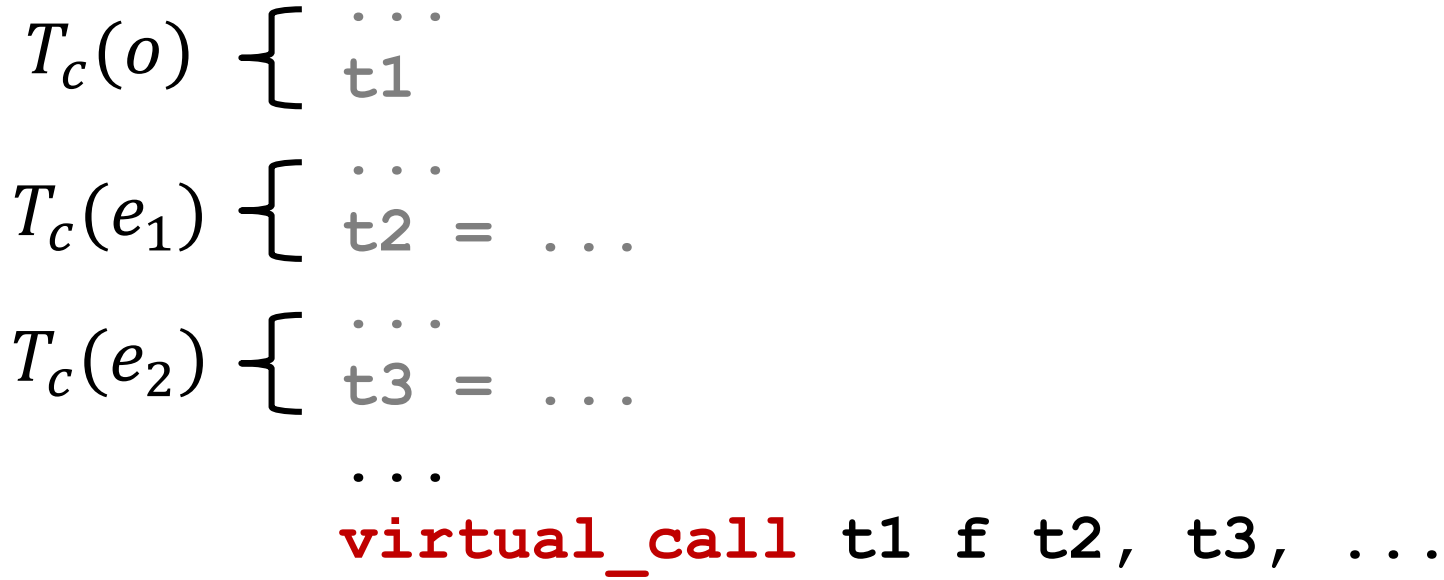
Translating Statements

For obj.flag = 7:

```
t1 = obj
t2 = 7
field_set t1, flag, t2
```

Translating Statements

For $o.f(e_1, e_2, \dots)$:



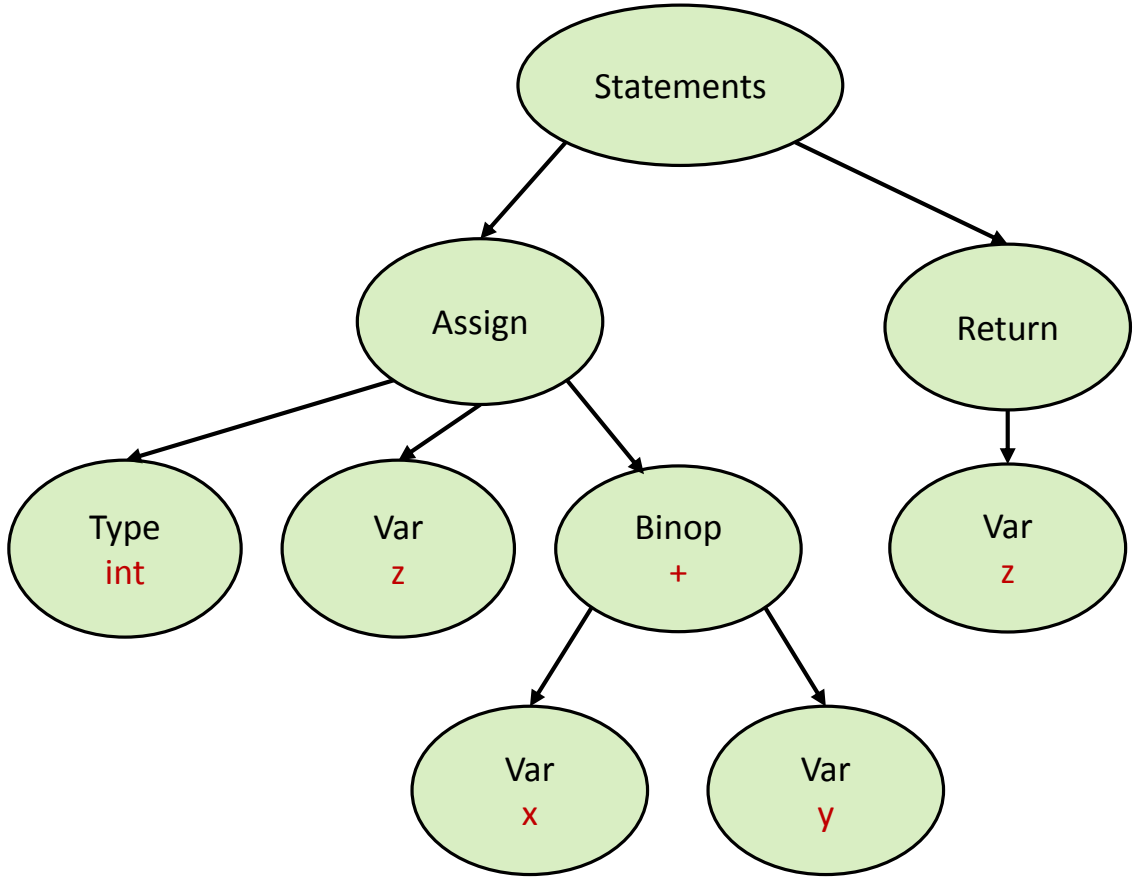
Translating Statements

For obj.bar(2, x + 1):

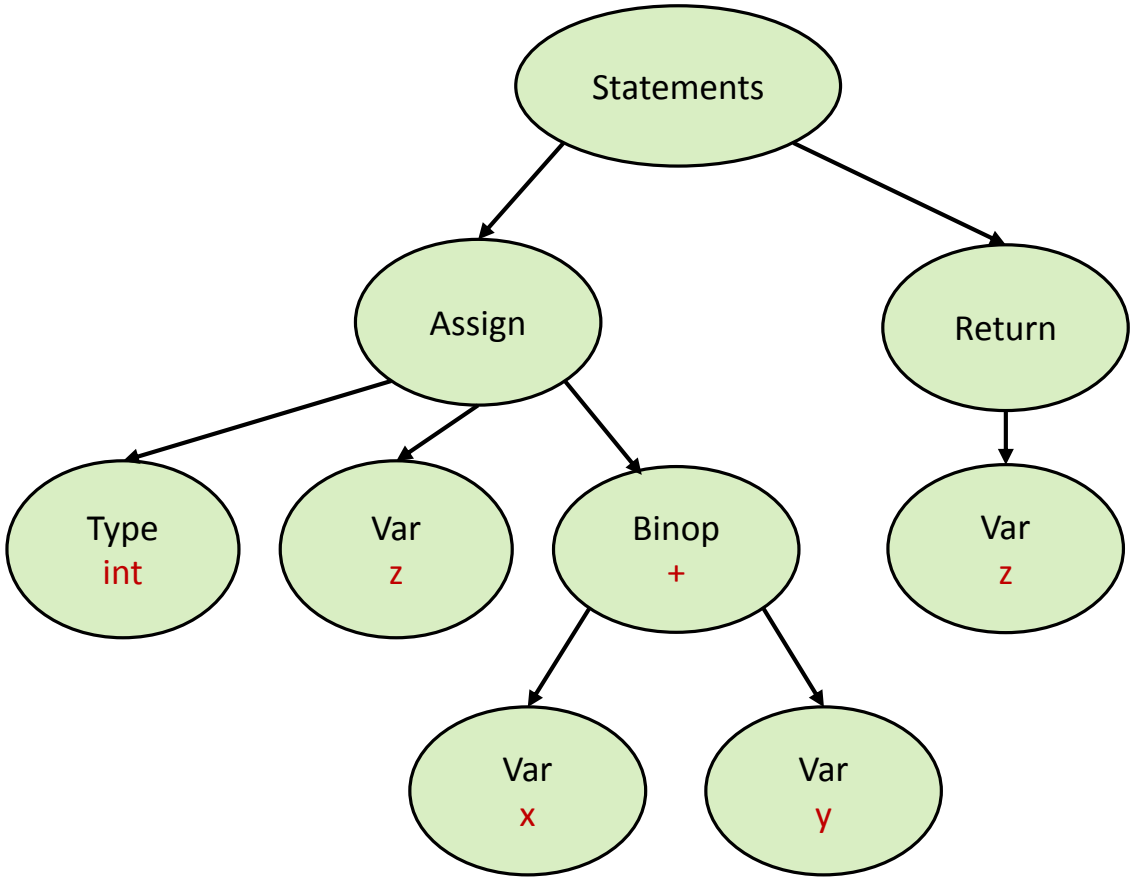
```
t1 = obj
t2 = 2
t3 = x
t4 = 1
t5 = add t3, t4
virtual_call t1, bar, t2, t5
```

Example

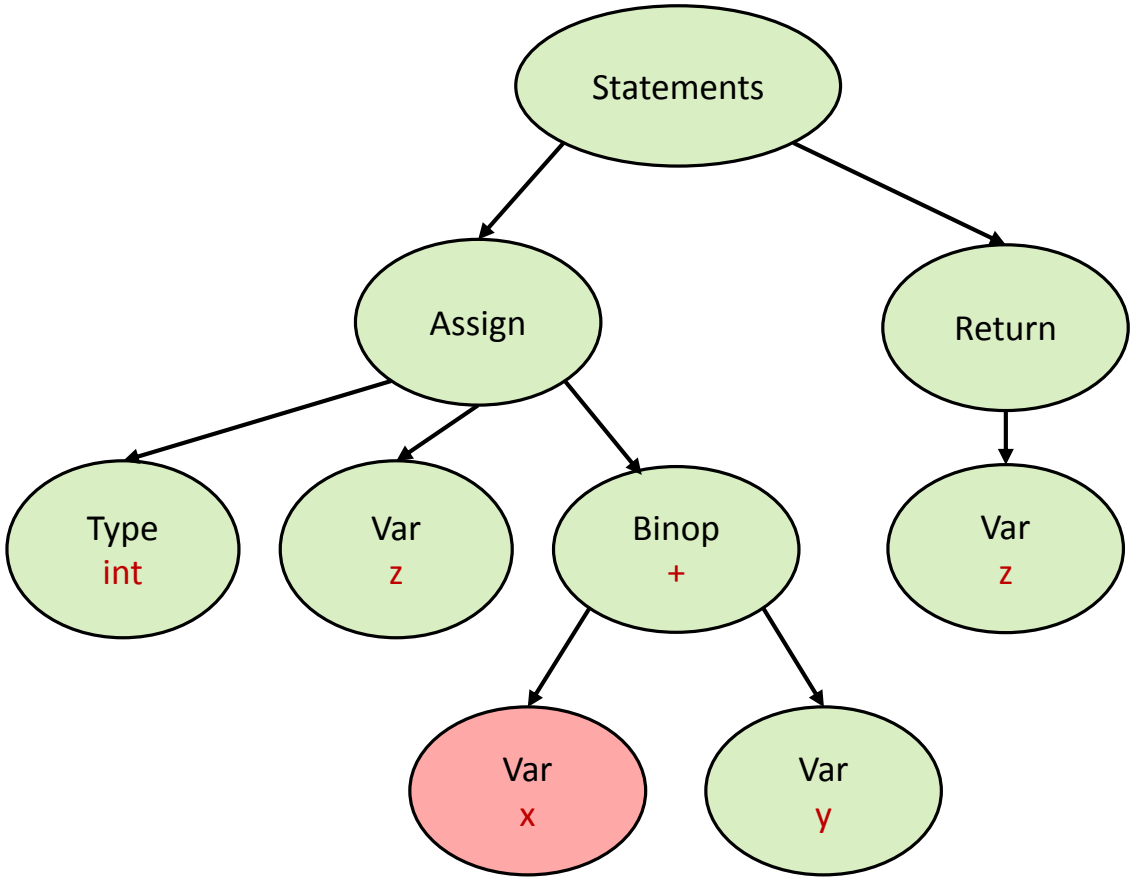
```
int f(int x, int y) {
  int z = x + y;
  return z;
}
```



Example

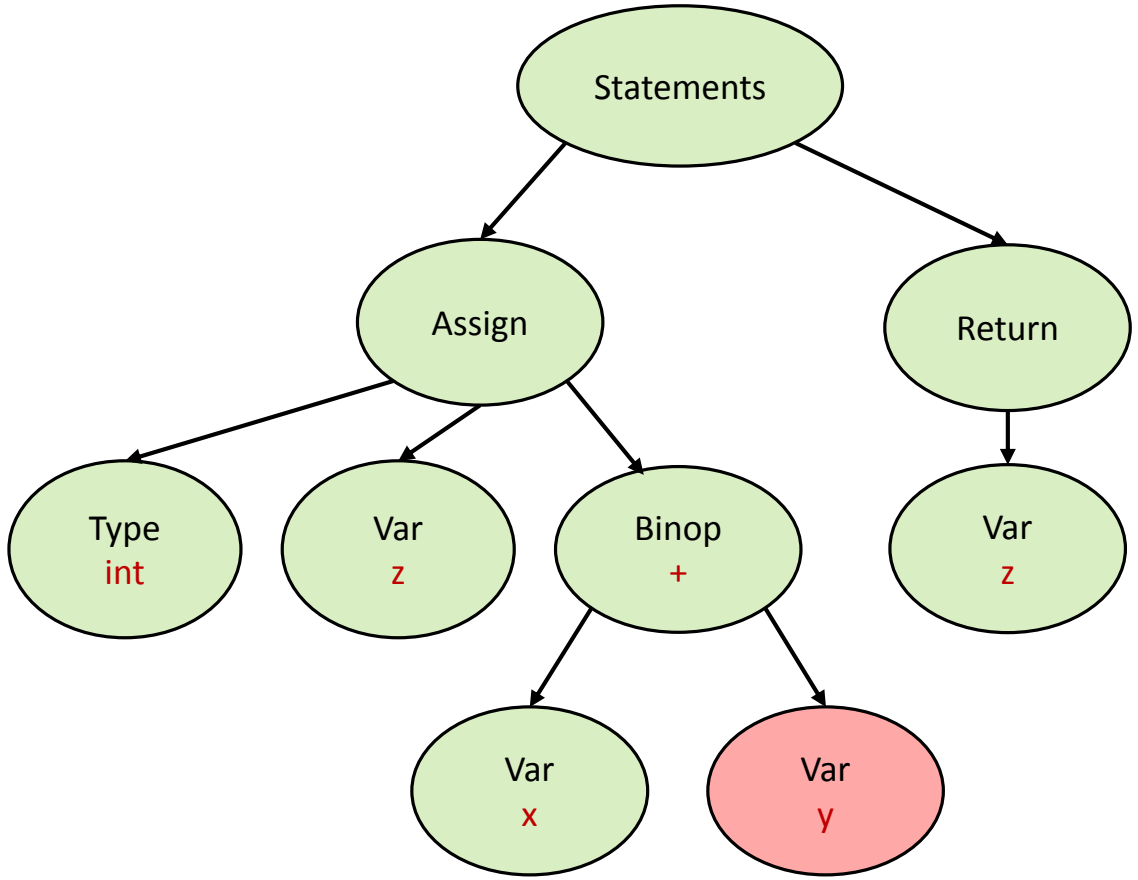

Statements
Assign
Return
Type
int
Var
z
Binop
+
Var
z
Var
x
Var
y

Example


Statements
Assign
Return
Type
int
Var
z
Binop
+
Var
z
Var
x
Var
y

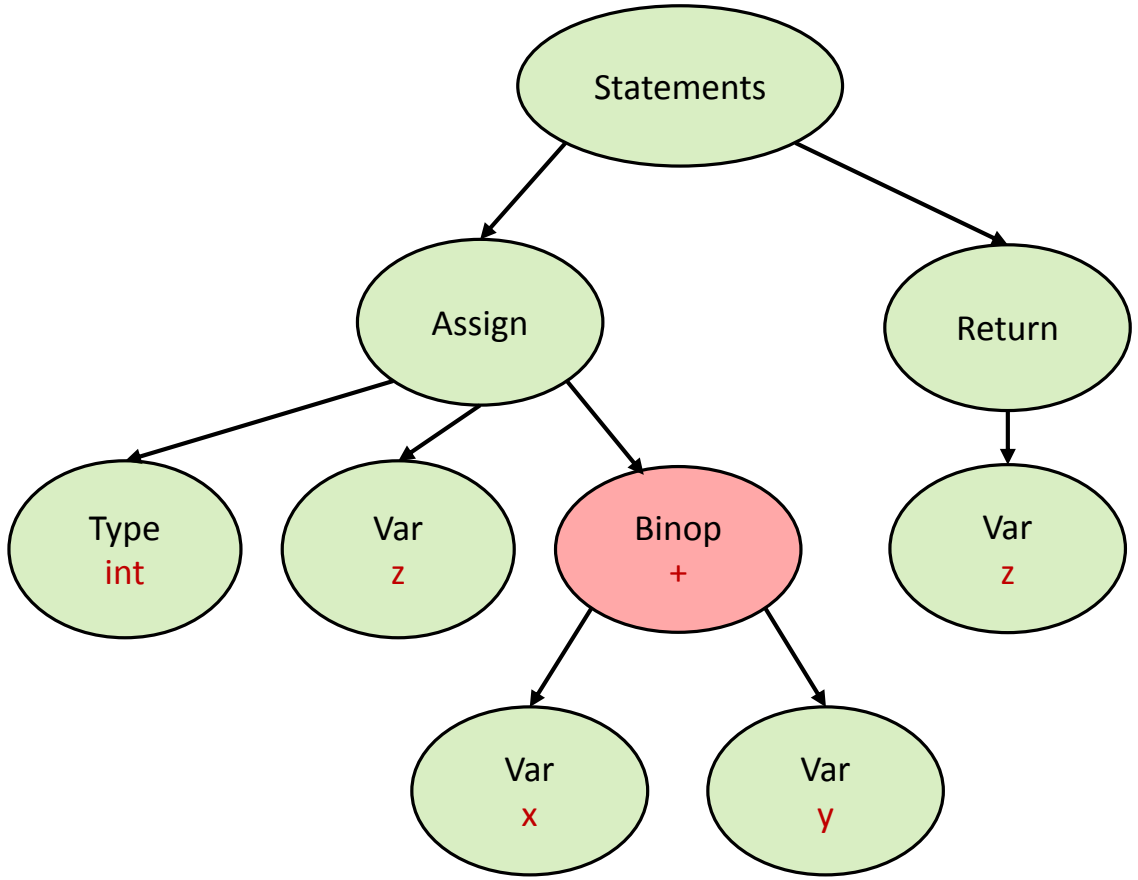
```
t1 = x
```

Example



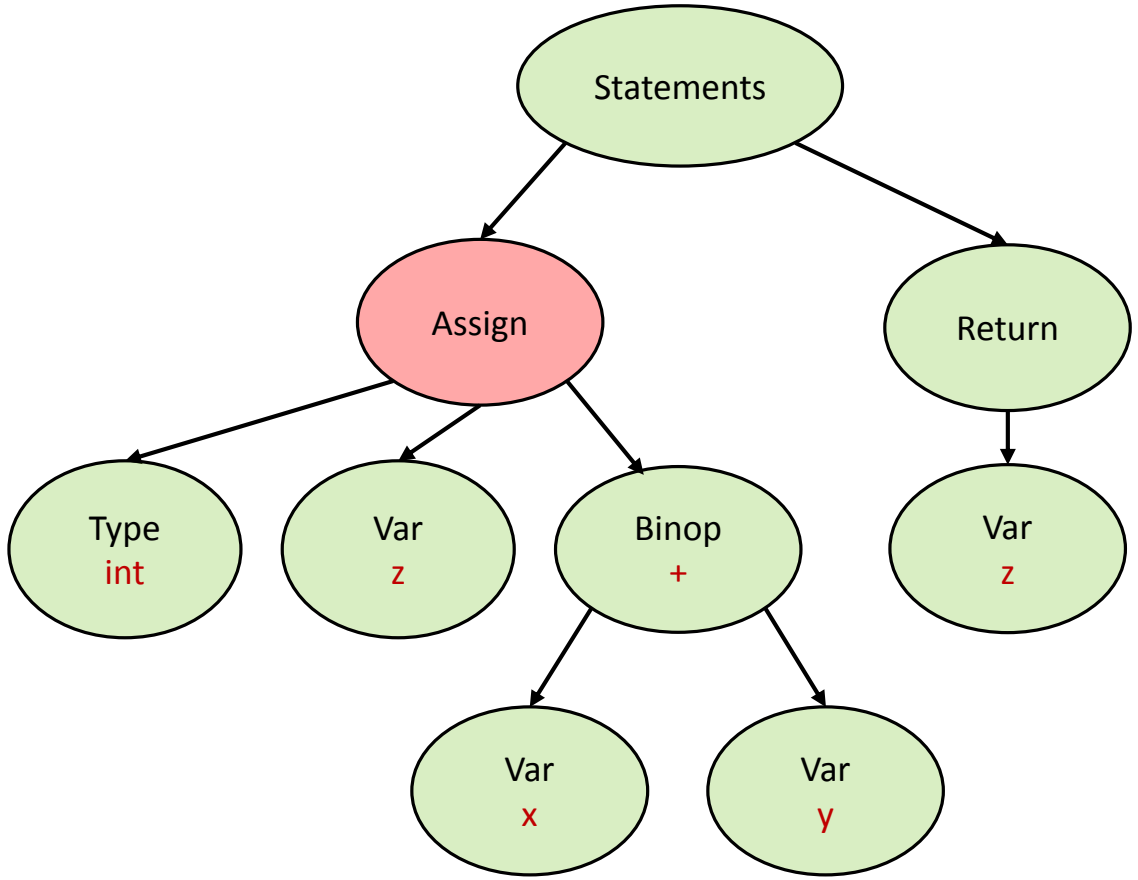

```
t1 = x          t2 = y
```

Example



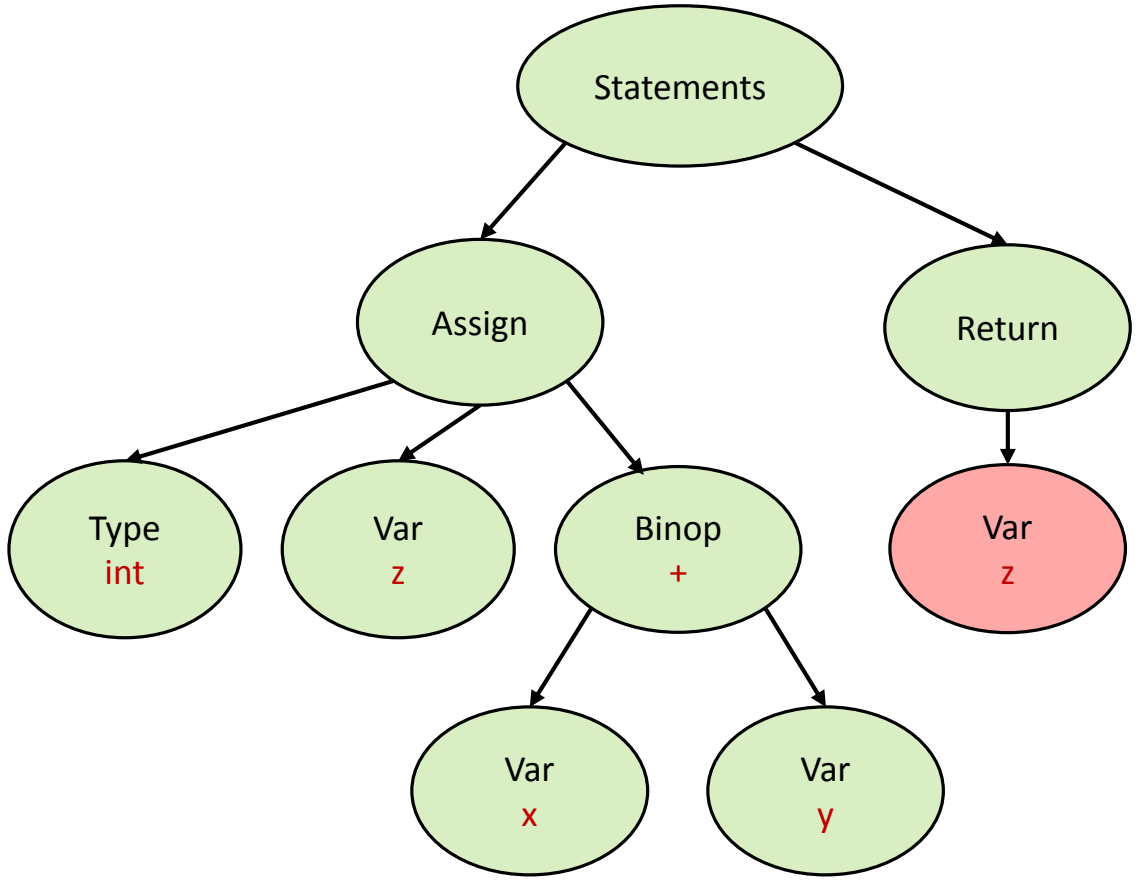

```
t1 = x
t2 = y
t3 = add t1, t2
```

Example




```
t1 = x
t2 = y
t3 = add t1, t2
z = t3
```

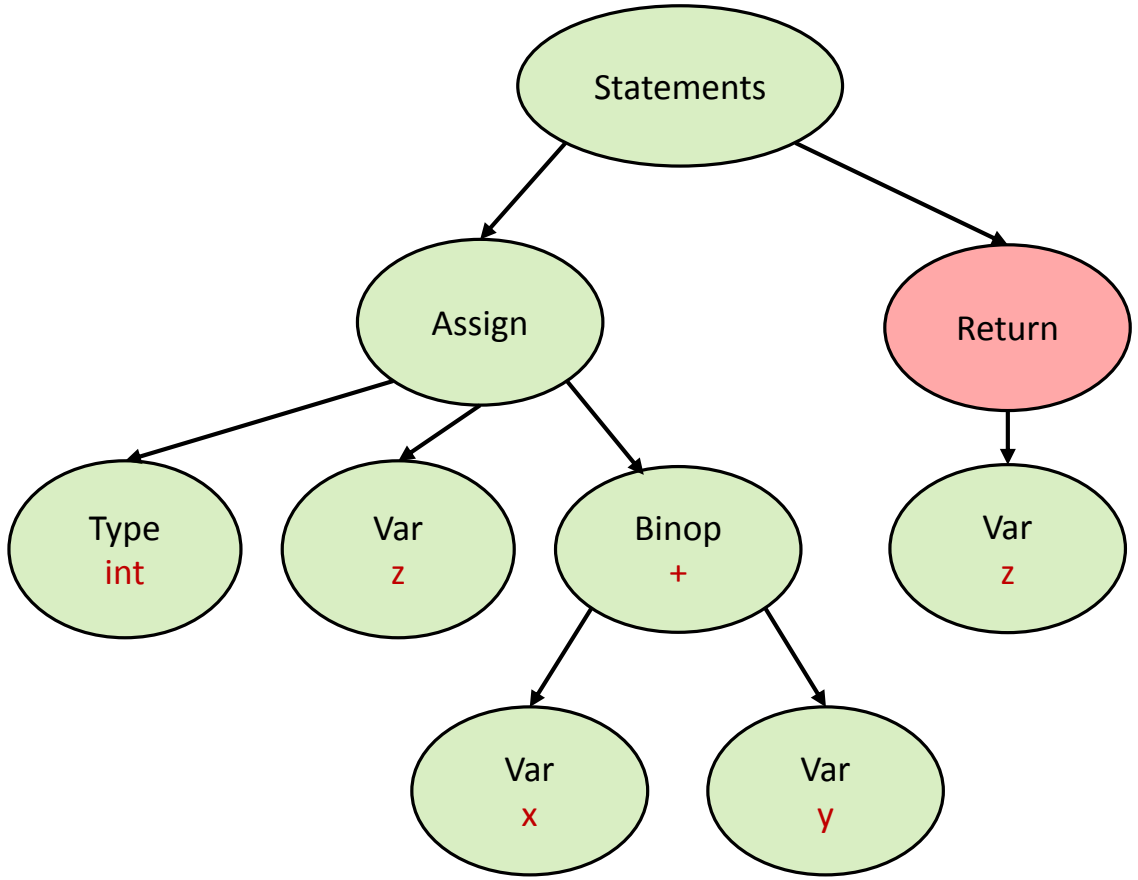
Example




```
t1 = x
t2 = y
t3 = add t1, t2
z = t3
```

```
t4 = z
```

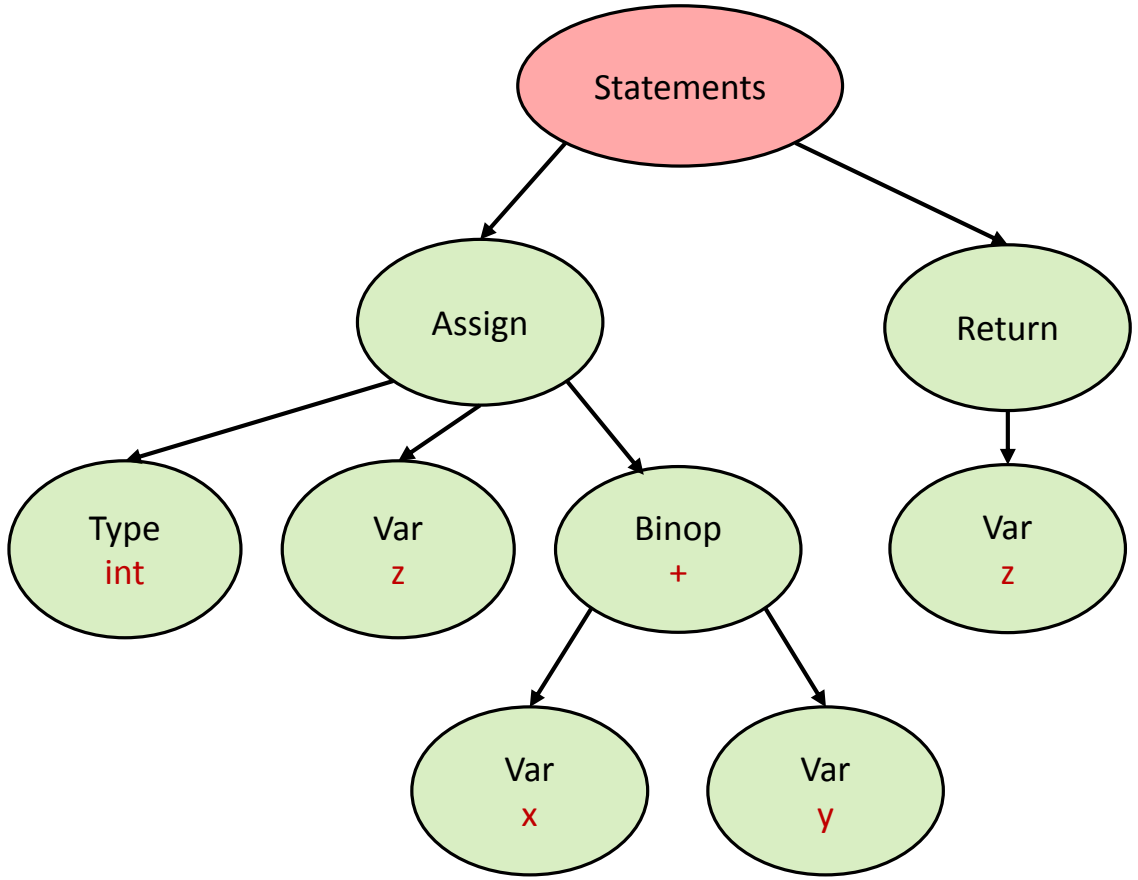
Example




```
t1 = x
t2 = y
t3 = add t1, t2
z = t3
```

```
t4 = z
return t4
```

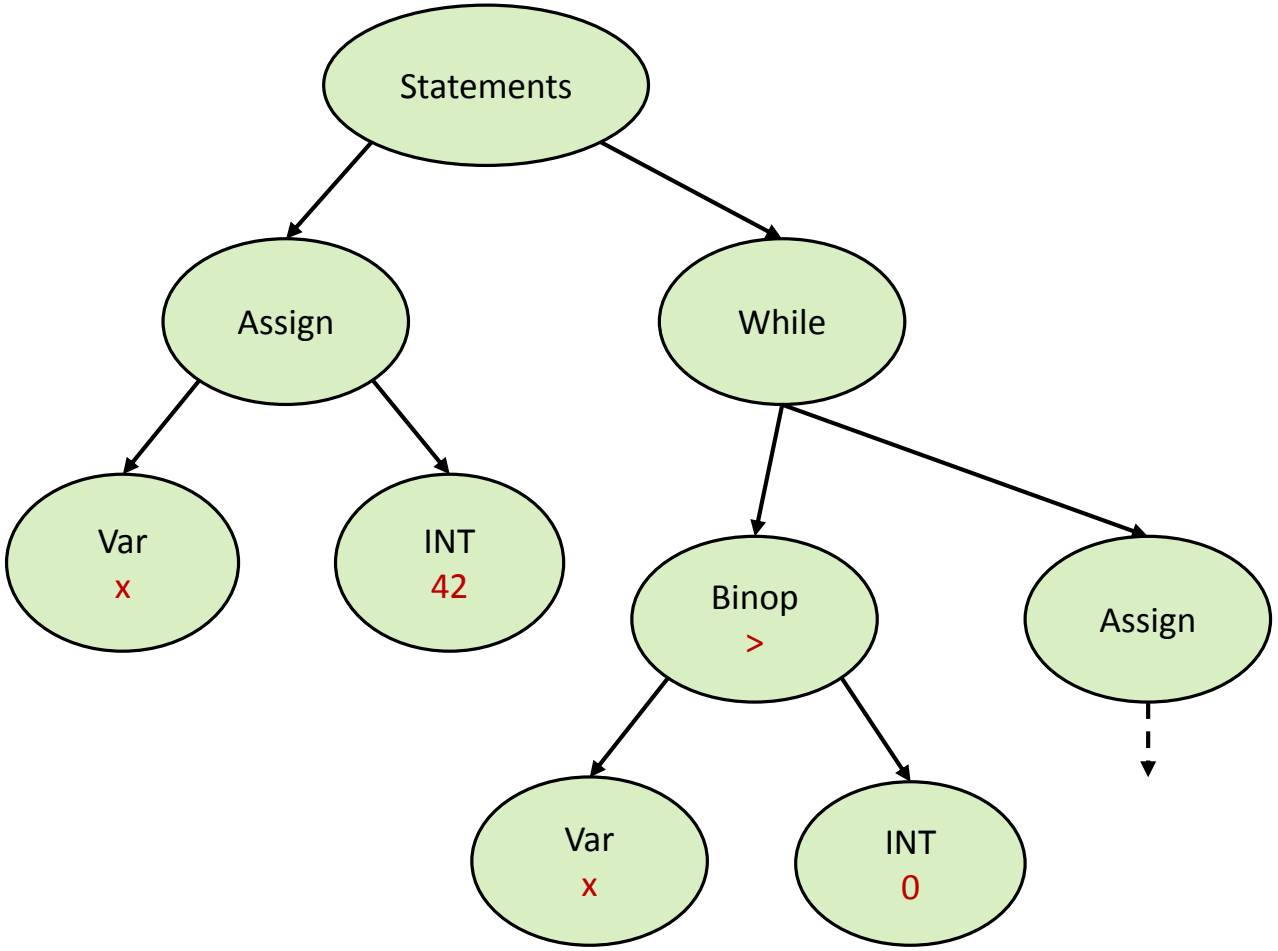
Example



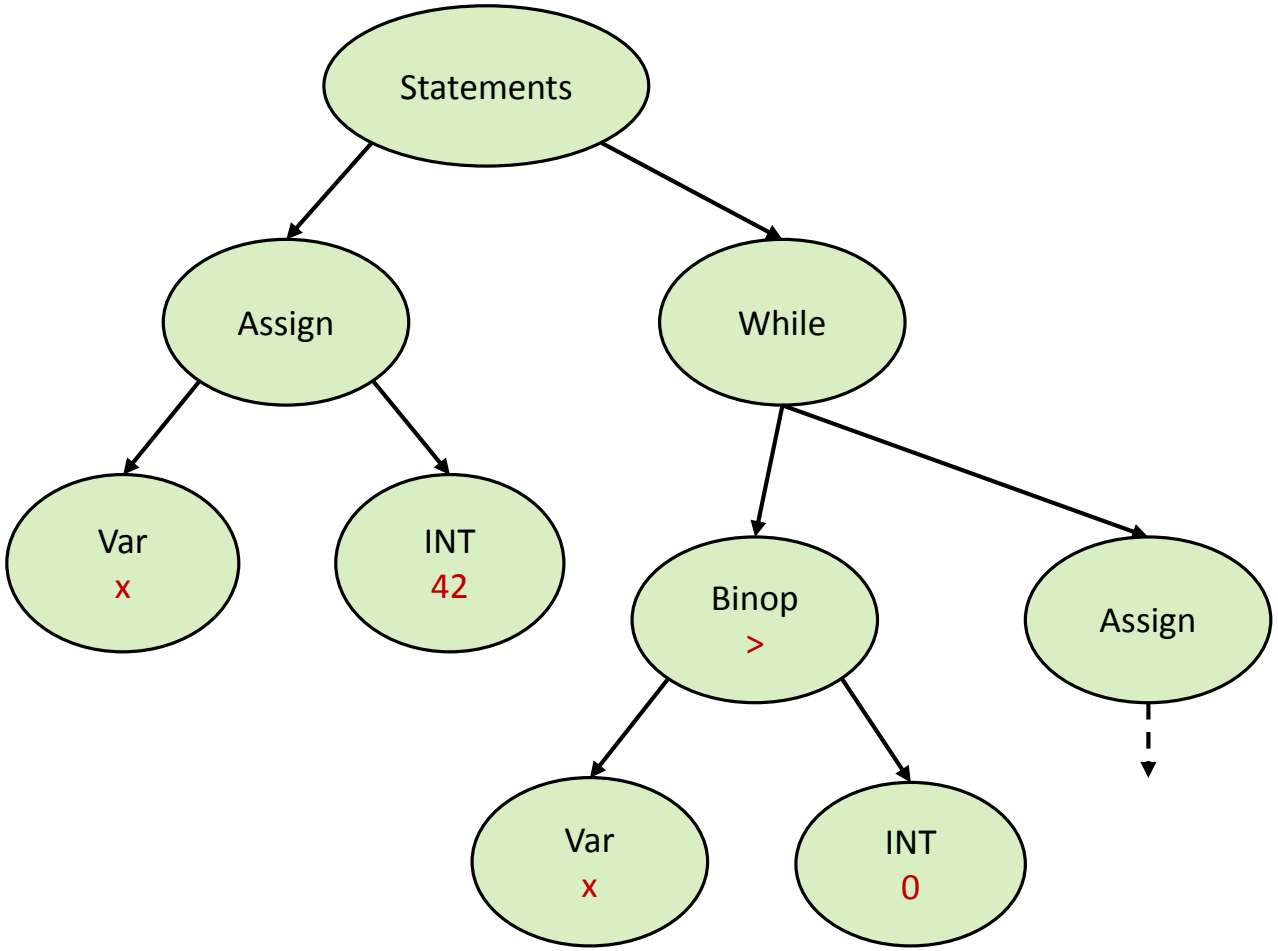

```
t1 = x
t2 = y
t3 = add t1, t2
z = t3
t4 = z
return t4
```

Example

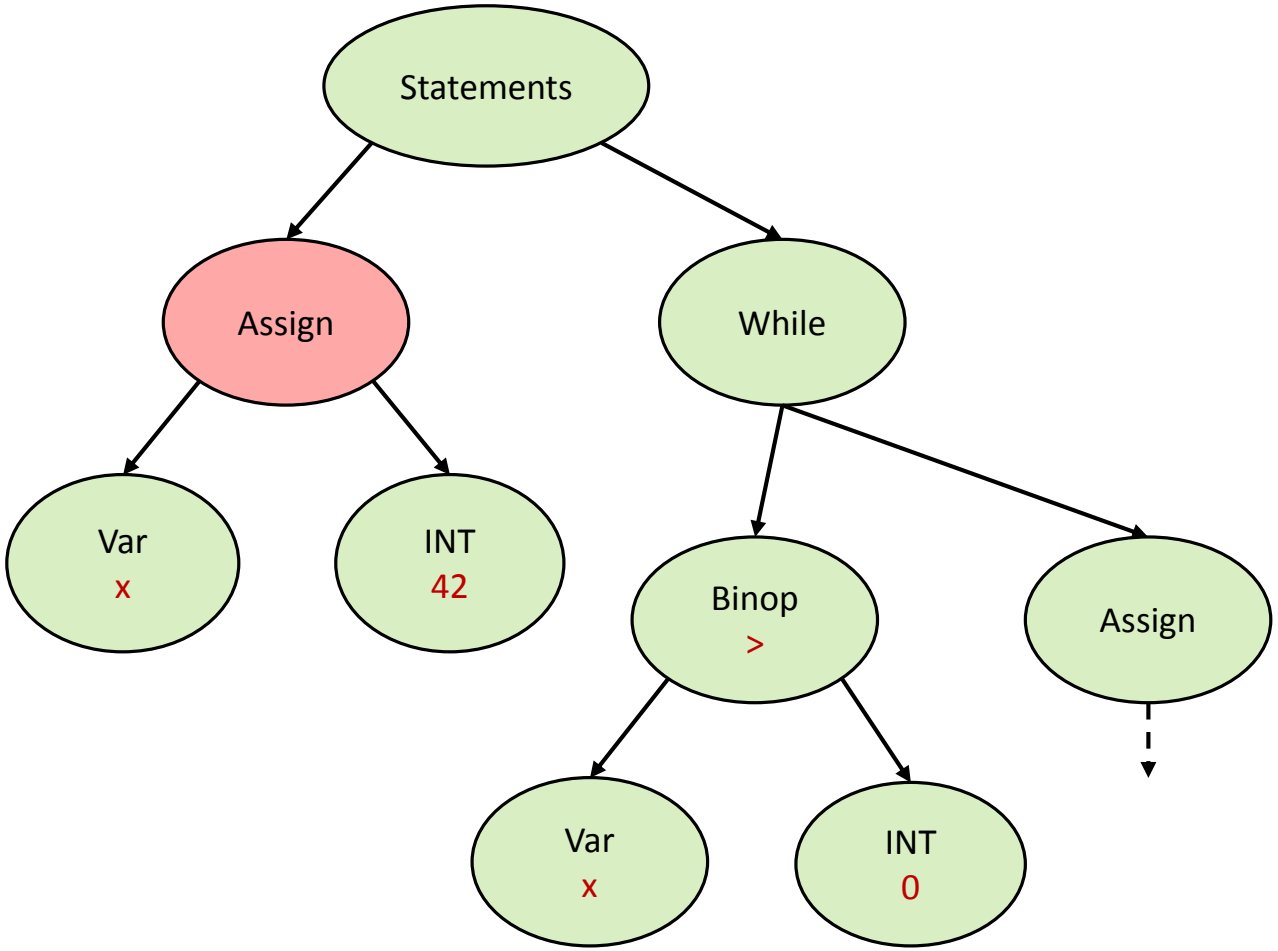
```
x = 42;
while (x > 0) {
   x = x - 1;
}
```



Example

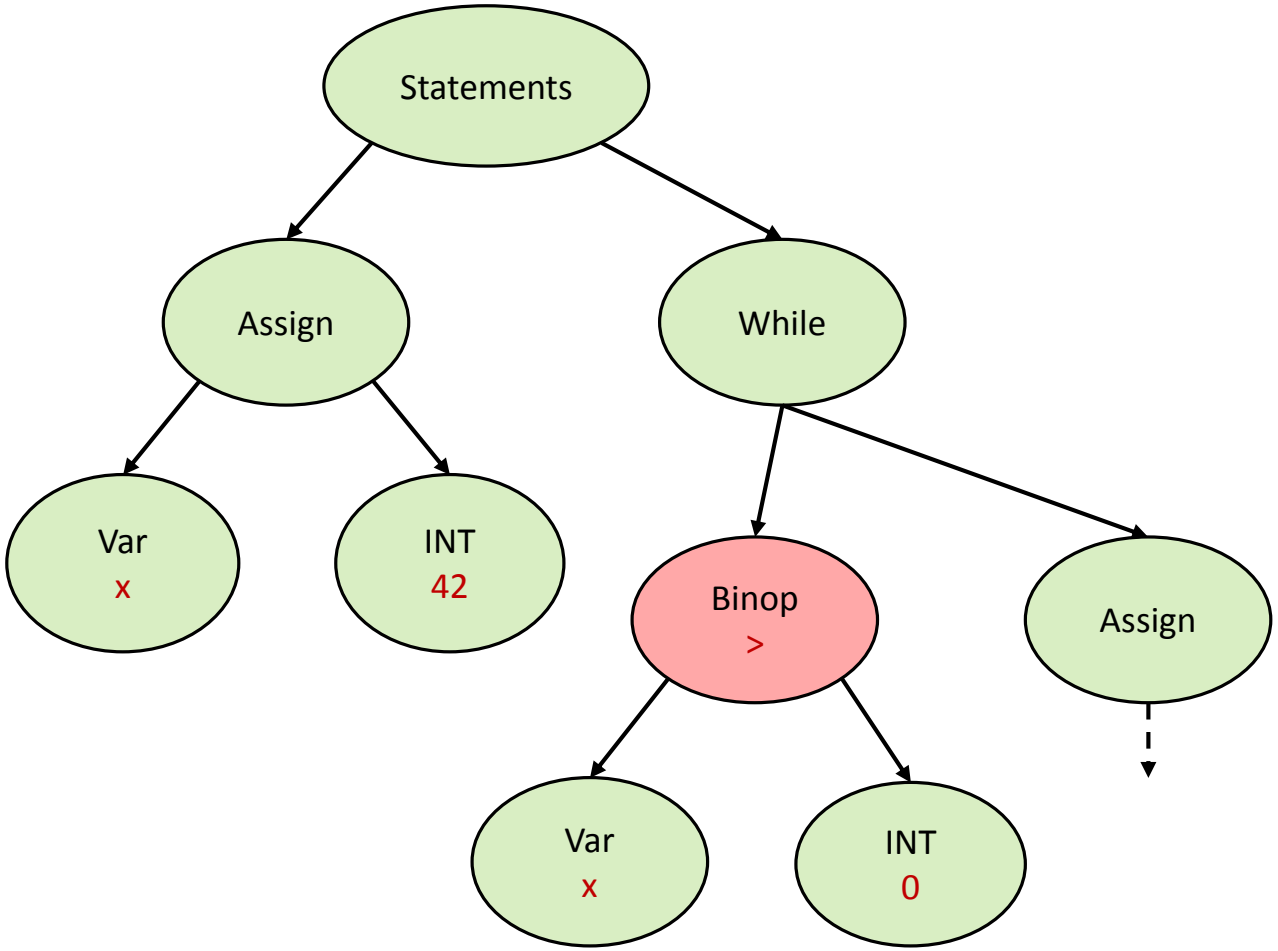


Example




```
t1 = 42
x = t1
```

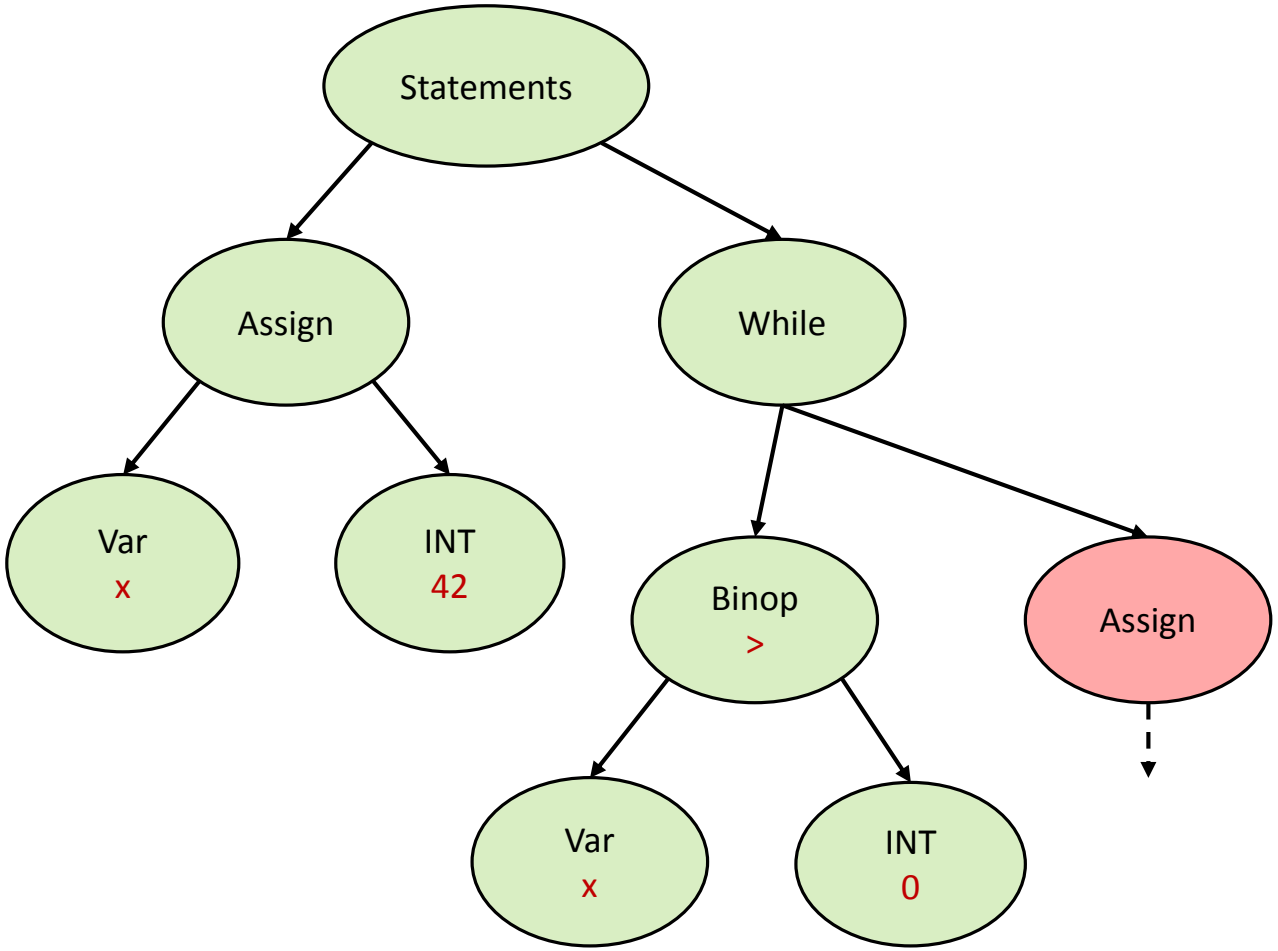
Example




```
t1 = 42
x = t1
```

```
t2 = x
t3 = 0
t4 = 1
bgt t2, t3, cmp_label:
t4 = 0
cmp_label:
```

Example

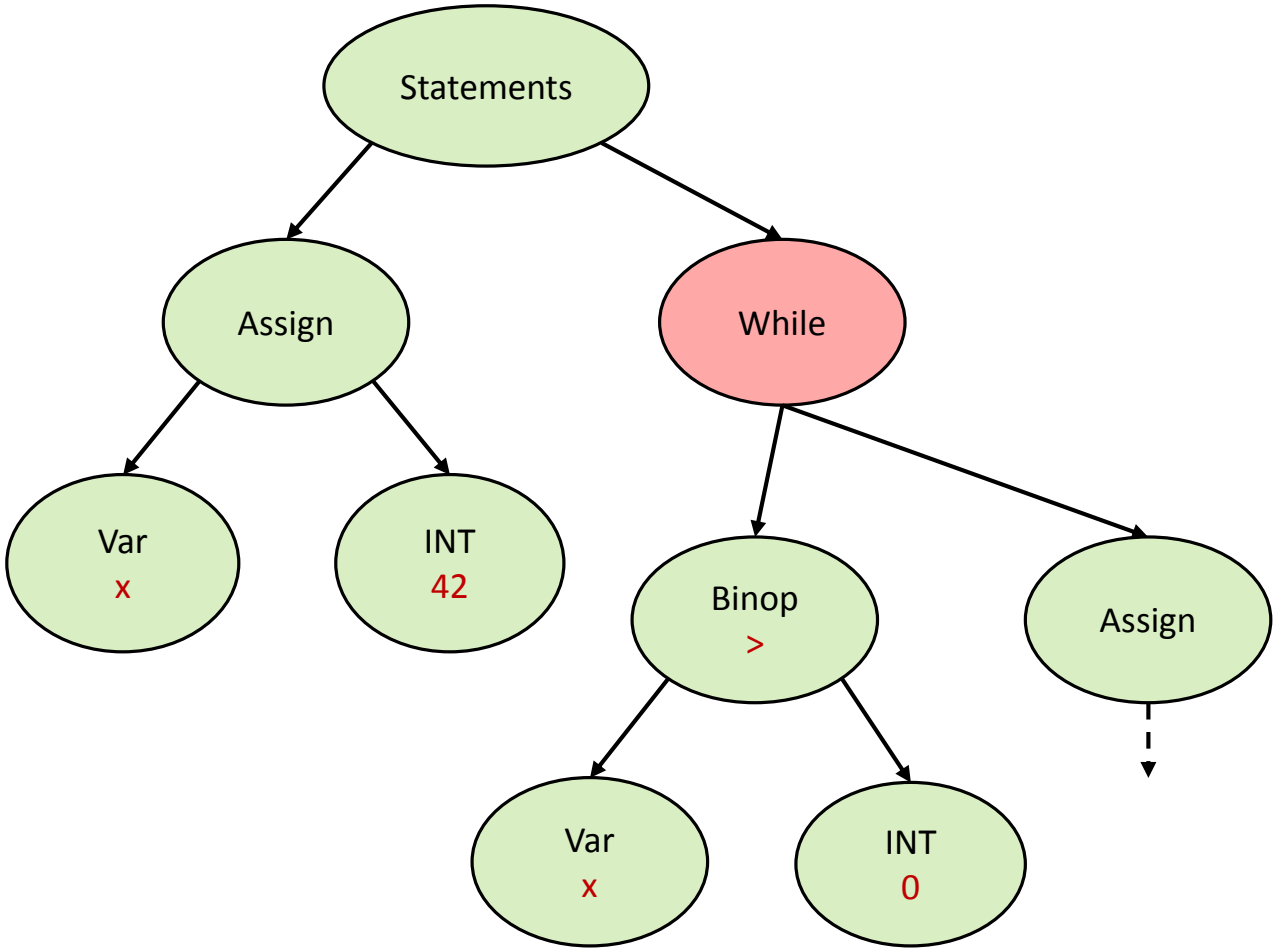



```
t1 = 42
x = t1
```

```
t2 = x
t3 = 0
t4 = 1
bgt t2, t3, cmp_label:
t4 = 0
cmp_label:

t5 = x
t6 = 1
t7 = sub t5, t6
x = t7
```

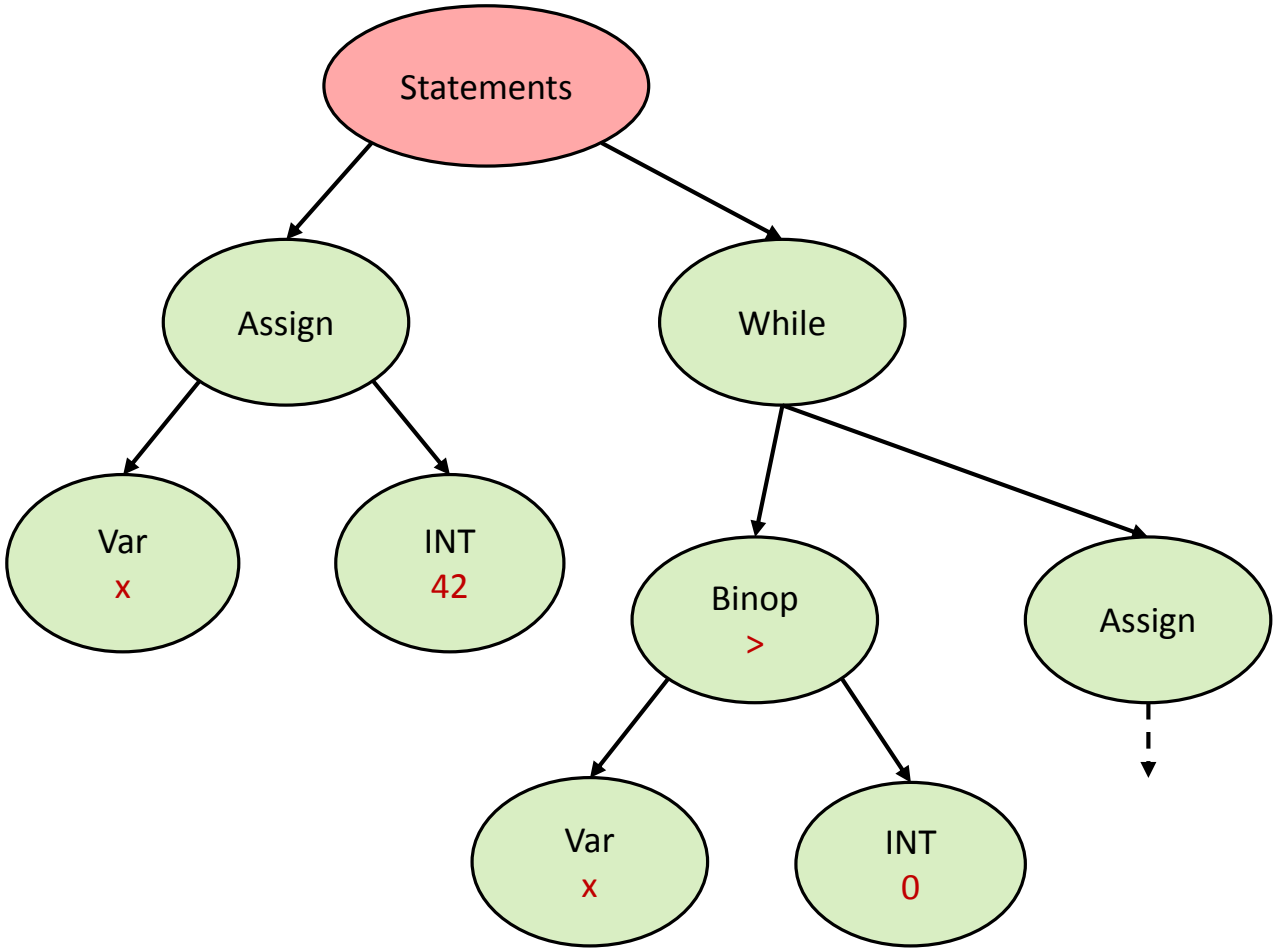
Example




```
t1 = 42
x = t1
```

```
cond_label:
t2 = x
t3 = 0
t4 = 1
bgt t2, t3, cmp_label:
t4 = 0
cmp_label:
beq t4, 0, end_label
t5 = x
t6 = 1
t7 = sub t5, t6
x = t7
br cond_label
end_label:
```

Example




```
t1 = 42
x = t1
cond_label:
t2 = x
t3 = 0
t4 = 1
bgt t2, t3, cmp_label:
t4 = 0
cmp_label:
beq t4, 0, end_label
t5 = x
t6 = 1
t7 = sub t5, t6
x = t7
br cond_label
end_label:
```