

# Semantic actions for control structures

# Statement lists

- So far we have discussed generating code for one assignment statement
- Generating code for multiple statements is easy

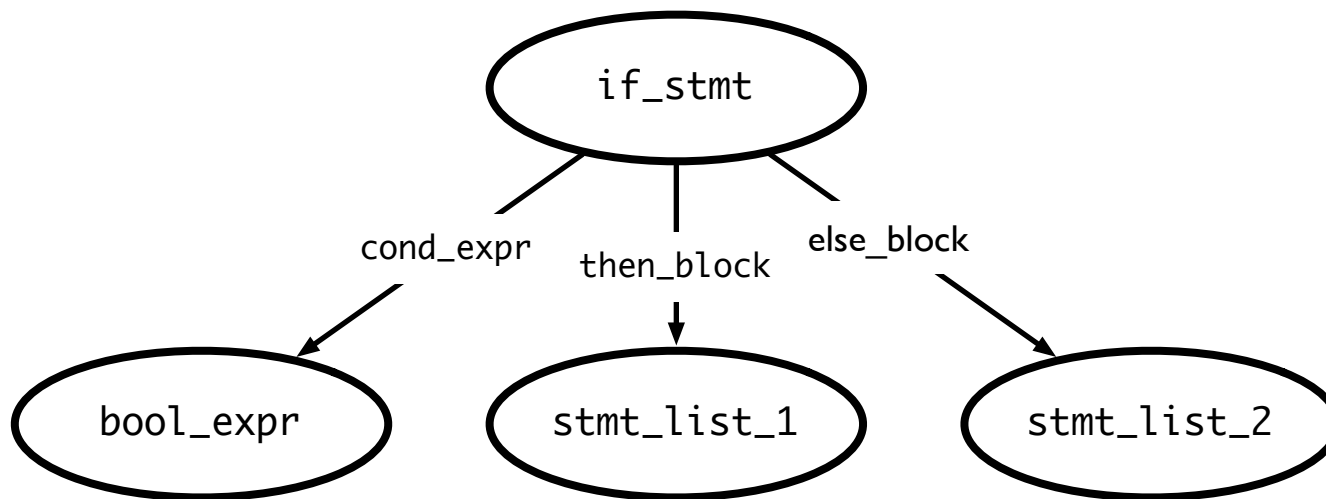
$$\text{stmt\_list} \rightarrow \text{stmt stmt\_list} \mid \lambda$$

- Keep appending (or prepending) the code generated by a single statement to the code generated by the rest of the statement list
- What if statement is not an assignment?

# If statements

```
if <bool_expr_1>  
    <stmt_list_1>  
else  
    <stmt_list_2>  
endif
```

# If statements



# Generating code for ifs

```
if <bool_expr_1>
    <stmt_list_1>
else
    <stmt_list_2>
endif

<code for bool_expr_1>
j<!op> ELSE_1
<code for stmt_list_1>
jmp OUT_1
ELSE_1:
    <code for stmt_list_2>
OUT_1:
```

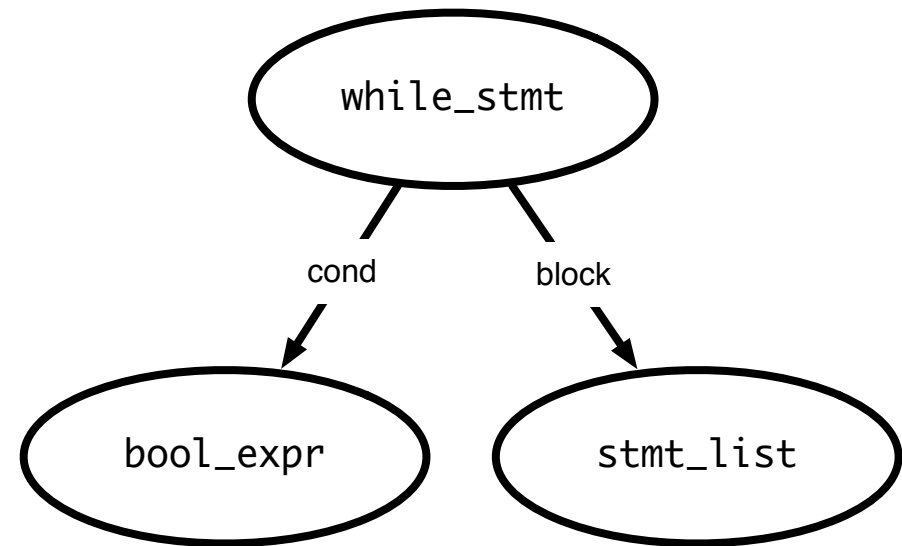
# Notes on code generation

- The `<op>` in `j<!op>` is dependent on the type of comparison you are doing in `<bool_expr>`
- When you generate JUMP instructions, you should also generate the appropriate LABELS
  - But you may not put the LABEL into the code immediately
    - e.g., the OUT label (when should you create this? When should you put this in code?)
  - Instead, generate the labels when you first process the if statement (i.e., before you process the children) so that it's available when necessary
- Remember: labels have to be unique!

# Processing Loops

# While loops

```
while <bool_expr>  
  <stmt_list>  
endwhile
```





# Generating code for while loops

```
while <bool_expr>  
  <stmt_list>  
endwhile;
```

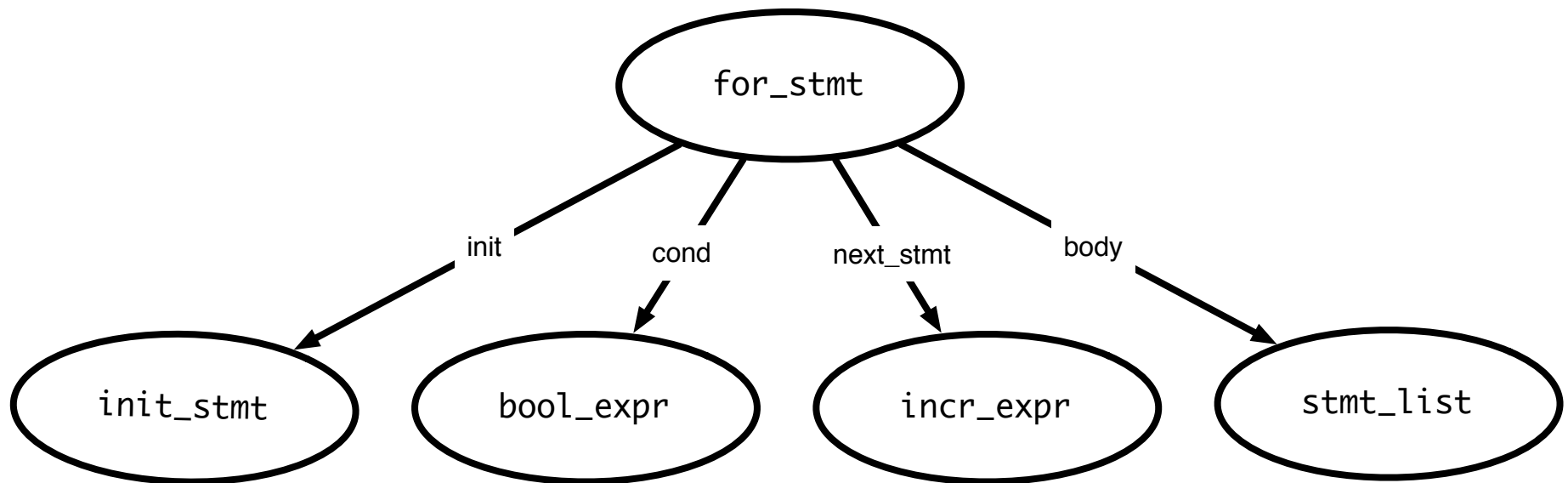


```
LOOP:  
  <bool_expr>  
  j<!op> OUT  
  <stmt_list>  
  jmp LOOP  
OUT:
```

- Re-evaluate expression each time
- Question: what would code for “repeat until” loop look like? For “do while”?

# For loops

```
for (<init_stmt>;<bool_expr>;<incr_stmt>)  
  <stmt_list>  
end
```



# Generating code: for loops

```
for (<init_stmt>; <bool_expr>; <incr_stmt>)  
    <stmt_list>  
end
```



```
<init_stmt>  
LOOP:  
    <bool_expr>  
    j<!op> OUT  
    <stmt_list>  
INCR:  
    <incr_stmt>  
    jmp LOOP  
OUT:
```

- Execute `init_stmt` first
- Jump out of loop if `bool_expr` is false
- Execute `incr_stmt` after block, jump back to top of loop
- Question: Why do we have the INCR label?

# continue and break statements

```
for (<init_stmt>; <bool_expr>; <incr_stmt>)  
    <stmt_list>  
end
```

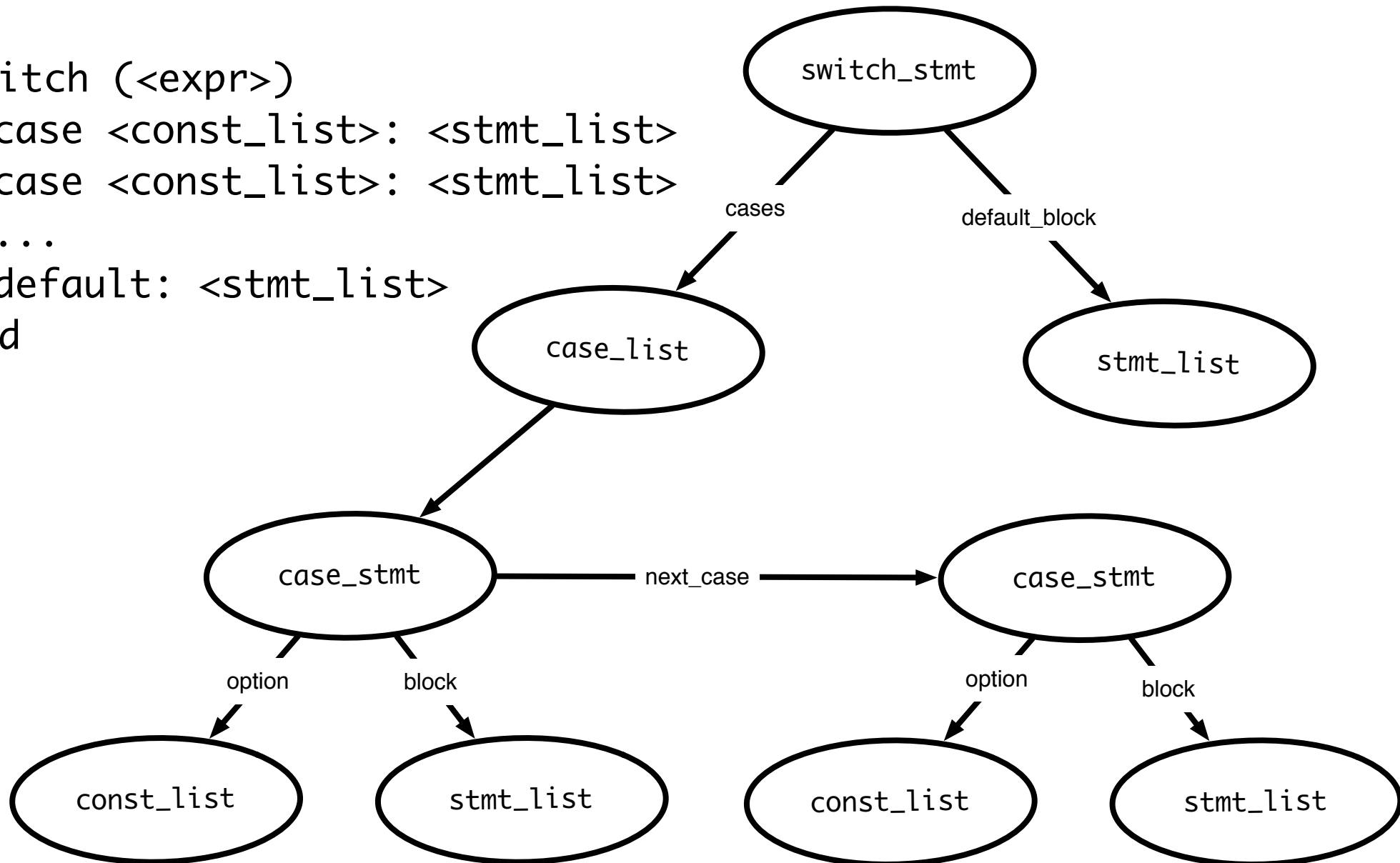


```
<init_stmt>  
LOOP:  
    <bool_expr>  
    j<!op> OUT  
    <stmt_list>  
INCR:  
    <incr_stmt>  
    jmp LOOP  
OUT:
```

- Continue statements: skip past rest of block, perform incr\_stmt and restart loop
- Break statements: jump out of loop (do not execute incr\_stmt)
- Caveats:
  - Code for stmt\_list is generated earlier—where do we jump?
  - Keep track of “loop depth” as you descend through AST

# Switch statements

```
switch (<expr>)  
  case <const_list>: <stmt_list>  
  case <const_list>: <stmt_list>  
  ...  
  default: <stmt_list>  
end
```



# Switch statements

```
switch (<expr>)  
  case <const_list>: <stmt_list>  
  case <const_list>: <stmt_list>  
  ...  
  default: <stmt_list>  
end
```

- Generated code should evaluate <expr> and make sure that some case matches the result
- Question: how to decide where to jump?

# Deciding where to jump

- Problem: do not know *which label* to jump to until switch expression is evaluated
- Use a jump table: an array indexed by case values, contains address to jump to
  - If table is not full (i.e., some possible values are skipped), can point to a default clause
    - If default clause does not exist, this can point to error code
- Problems
  - If table is sparse, wastes a lot of space
  - If many choices, table will be very large

# Jump table example

Consider the code:  
((**xxxx**) is address of code)

Jump table has 6 entries:

Case x is  
(**0010**) When 0: stmts  
(**0017**) When 1: stmts  
(**0192**) When 2: stmts  
(**0198**) When 3 stmts;  
(**1000**) When 5 stmts;  
(**1050**) Else stmts;

Table only has one  
Unnecessary row  
(for choice 4)

0	JUMP 0010
1	JUMP 0017
2	JUMP 0192
3	JUMP 0198
4	JUMP 1050
5	JUMP 1000



# Jump table example

Consider the code:  
((**xxxx**) Is address of code)

Jump table has 6 entries:

Case x is  
(**0010**) When 0: stmts0  
(**0017**) When 1: stmts1  
(**0192**) When 2: stmts2  
(**0198**) When 3: stmts3  
(**1000**) When 987: stmts4  
(**1050**) When others: stmts5

0	JUMP 0010
1	JUMP 0017
2	JUMP 0192
3	JUMP 0198
4	JUMP 1050
...	JUMP 1050
986	JUMP 1050
987	JUMP 1000

Table only has 983 unnecessary rows.  
Doesn't appear to be the right thing to do! **NOTE: table size is proportional to range of choice clauses, not number of clauses!**

# Do a binary search

Consider the code: ((xxxx) is address of code)

Jump table has 6 entries:

Case x is

(0010) When 0: stmts0

(0017) When 1: stmts1

(0192) When 2: stmts2

(0198) When 3: stmts3

(1000) When 987: stmts4

(1050) When others: stmts5

0	JUMP 0010
1	JUMP 0017
2	JUMP 0192
3	JUMP 0198
987	JUMP 1000

Perform a binary search on the table. If the entry is found, then jump to that offset. If the entry isn't found, jump to others clause.  $O(\log n)$  time,  $n$  is the size of the table, for each jump.

# Linear search example

Consider the code:

(xxxx) Is offset of local  
Code start from the  
Jump instruction

Case x is

(0010) When 0: stmts

(0017) When 1: stmts

(0192) When 2: stmts

(1050) When others stmts;

If there are a small number of choices, then do an in-line linear search. A straightforward way to do this is generate code analogous to an IF THEN ELSE.

If (x == 0) then stmts1;

Elseif (x = 1) then stmts2;

Elseif (x = 2) then stmts3;

Else stmts4;

$O(n)$  time, n is the size of the table, for each jump.

# Dealing with jump tables

```
switch (<expr>)  
  case <const_list>: <stmt_list>  
  case <const_list>: <stmt_list>  
  ...  
  default: <stmt_list>  
end
```

```
  <expr>  
  <code for jump table>  
LABEL0:  
  <stmt_list>  
LABEL1:  
  <stmt_list>  
...  
DEFAULT:  
  <stmt_list>  
OUT:
```

- Generate labels, code, then build jump table
- Put jump table after generated code
- Why do we need the OUT label?
  - In case of break statements