

CS536

Syntax Directed Translation

CFGs so Far

- CFGs for Language *Definition*
 - The CFGs we've discussed can generate/define languages of valid strings
 - So far, we **start** by building a parse tree and **end** with some valid string
- CFGs for Language *Recognition*
 - Start with a string and end with a parse tree for it

CFGs for Parsing

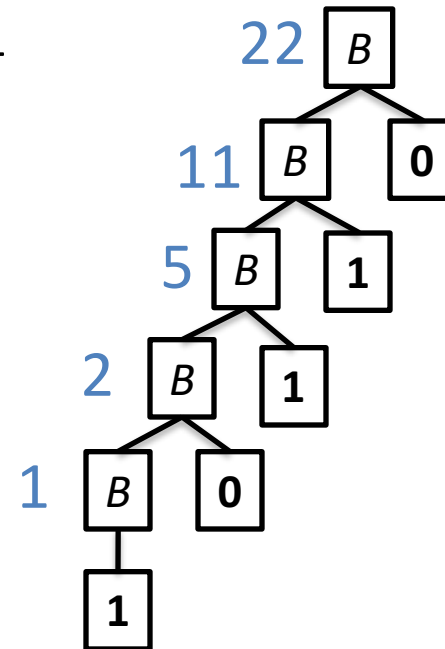
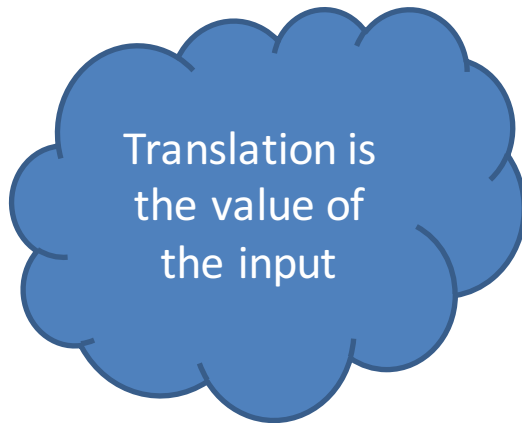
- Language Recognition isn't enough for a parser
 - We also want to *translate* the sequence
- Parsing is a special case of *Syntax-Directed Translation*
 - Translate a sequence of tokens into a sequence of actions

Syntax Directed Translation

- Augment CFG rules with translation rules (at least 1 per production)
 - Define translation of LHS nonterminal as a function of
 - Constants
 - RHS nonterminal translations
 - RHS terminal value
- Assign rules bottom up

SDT Example

<u>CFG</u>	<u>Rules</u>	<u>Input string</u>
$B \rightarrow 0$	$B.trans = 0$	10110
$ 1$	$B.trans = 1$	
$ B 0$	$B.trans = B_2.trans * 2$	
$ B 1$	$B.trans = B_2.trans * 2 + 1$	



SDT Example 2: Declarations

Translation is a
String of ids

CFG

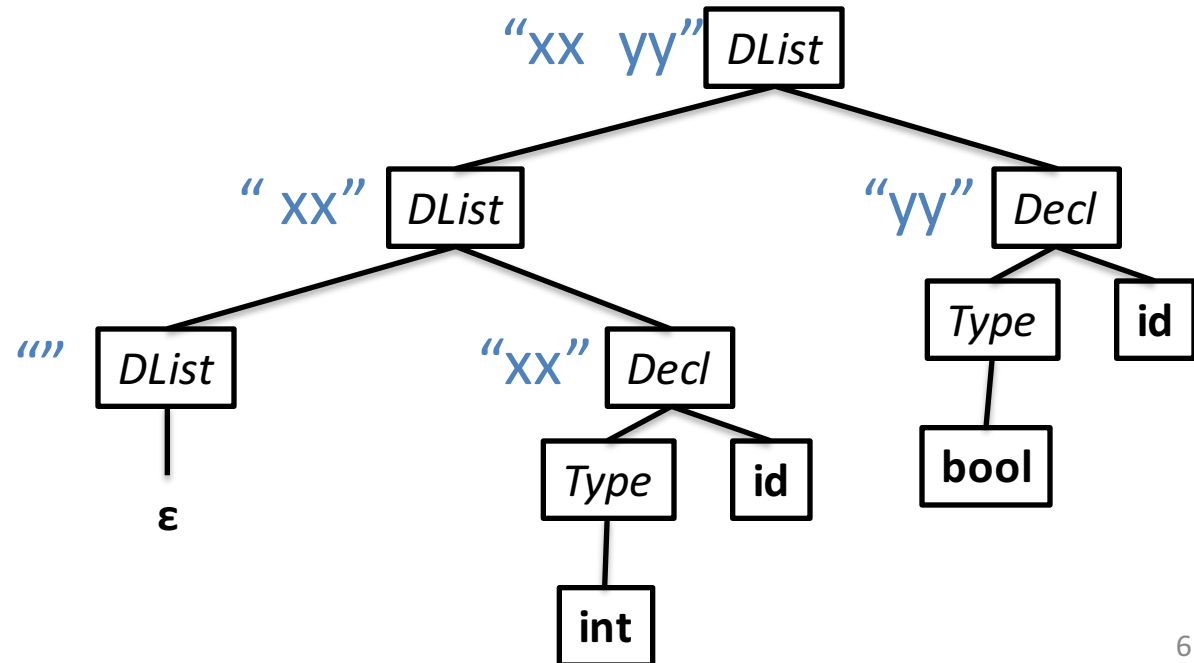
DList $\rightarrow \epsilon$
| *DList Decl*
Decl \rightarrow *Type id* ;
Type \rightarrow **int**
| **bool**

Rules

DList.trans = ""
DList.trans = *Decl.trans* + " " + *DList*₂.*trans*
Decl.trans = **id.value**

Input string

int xx;
bool yy;



Exercise Time

Only add declarations of type `int` to the output String.

Augment the previous grammar:

<u>CFG</u>	<u>Rules</u>
$DList \rightarrow \epsilon$	$DList.trans = ""$
$\quad \quad \quad Decl \ DList$	$DList.trans = Decl.trans + " " + DList_2.trans$
$Decl \rightarrow Type \ \mathbf{id} ;$	$Decl.trans = \mathbf{id.value}$
$Type \rightarrow \mathbf{int}$	
$\quad \quad \quad \mathbf{bool}$	

Different nonterms can
have different types

Rules can have conditionals

SDT Example 2b: ints only

Translation is a
String of **int** ids
only

CFG

DList $\rightarrow \epsilon$
| *Decl DList*
Decl \rightarrow *Type id* ;
Type \rightarrow **int**
| **bool**

Rules

DList.trans = ""

DList.trans = *Decl.trans* + " " + *DList₂.trans*

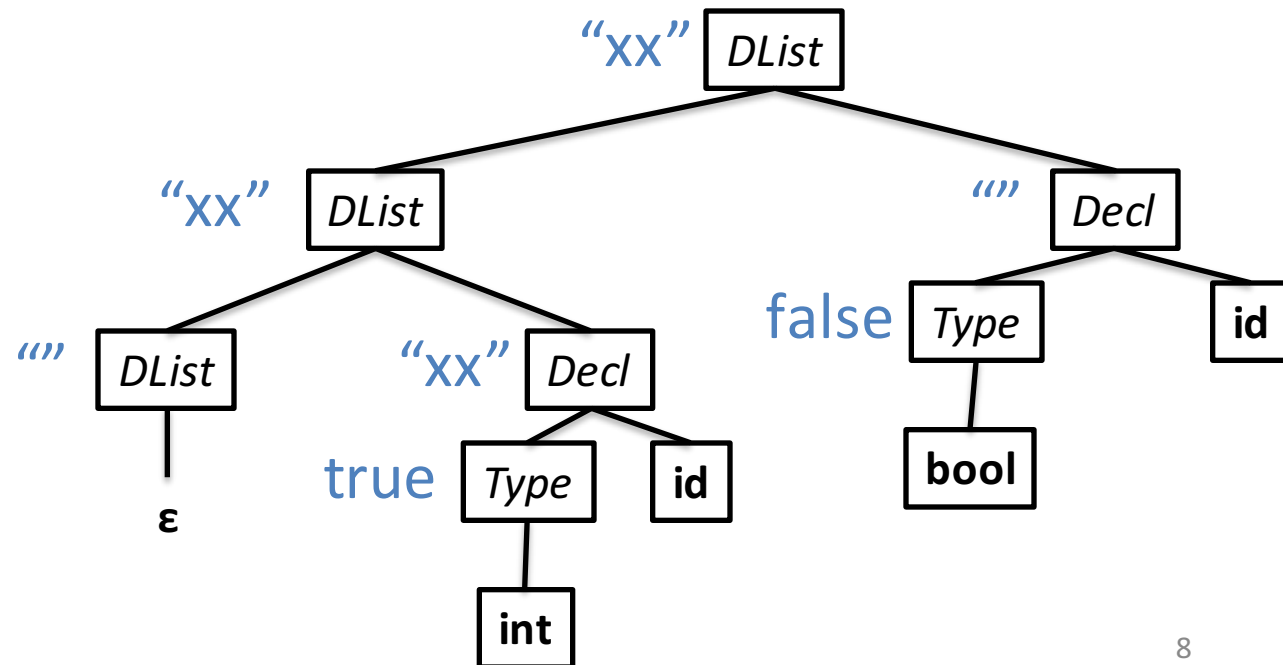
if (*type.trans*) {*Decl.trans* = **id.value**} else {*Decl.trans* = ""}

Type.trans = true

Type.trans = false

Input string

int xx;
bool yy;



Different nonterms can
have different types

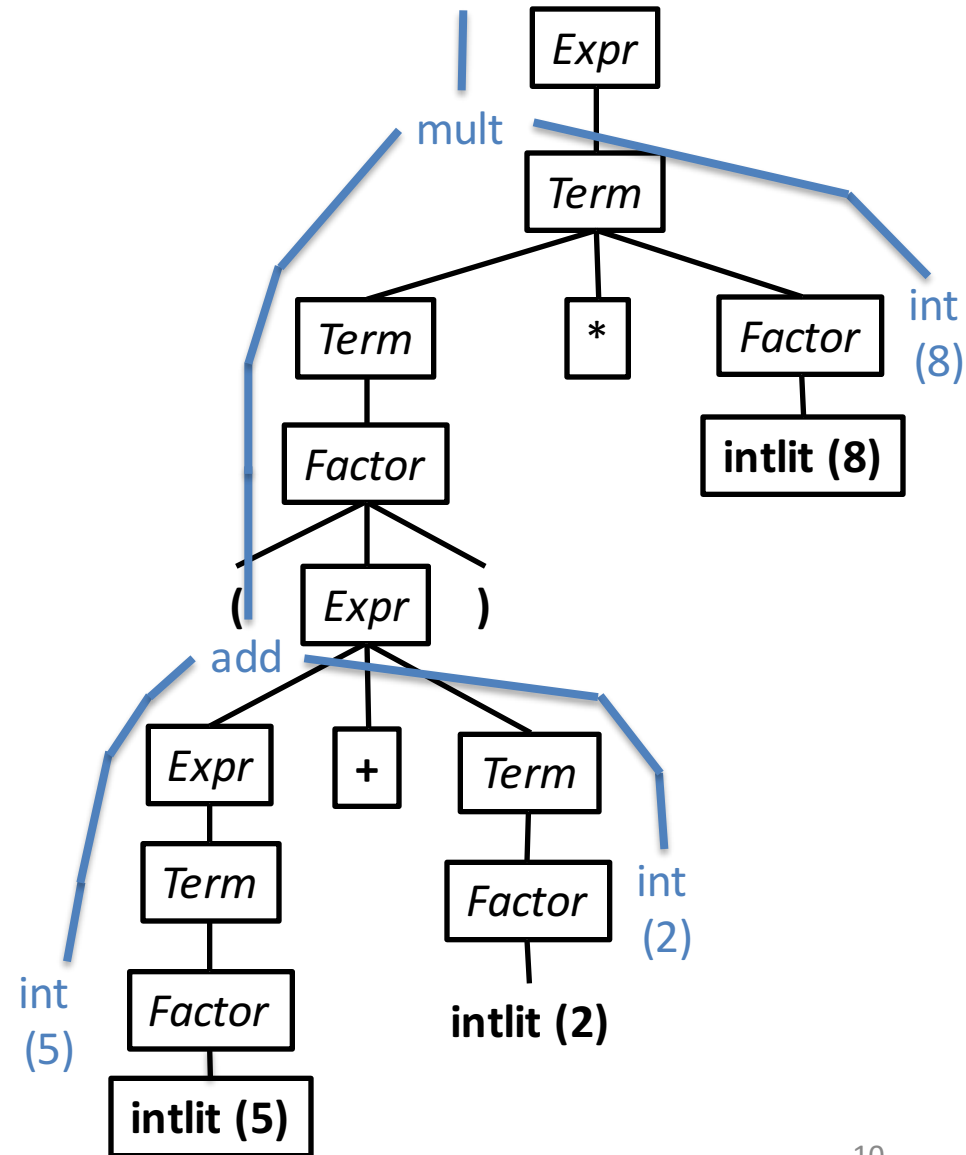
Rules can have conditionals

SDT for Parsing

- In the previous examples, the SDT process assigned different types to the translation:
 - Example 1: tokenized stream to an **integer value**
 - Example 2: tokenized stream to a (java) **String**
- For parsing, we'll go from tokens to an Abstract-Syntax Tree (AST)

Parse Tree

- Example: $(5+2)*8$



Exercise #2

- Show the AST for:

$(1 + 2) * (3 + 4) * 5 + 6$

Expr \rightarrow Expr + Term

| Term

Term \rightarrow Term * Factor

| Factor

Factor \rightarrow intlit

| (Expr)

AST for Parsing

- In previous slides we did our translation in two steps
 - Structure the stream of tokens into a parse tree
 - Use the parse tree to build an abstract syntax tree, throw away the parse tree
- In practice, we will combine these into 1 step
- Question: Why do we even need an AST?
 - More of a “logical” view of the program
 - Generally easier to work with

AST Implementation

- How do we actually represent an AST in code?
- We'll take inspiration from how we represented tokens in JLex

ASTs in Code

- Note that we've assumed a field-like structure in our SDT actions:

DList.trans = *Decl.trans* + " " + *DList₂.trans*

- In our parser, we'll define classes for each type of nonterminal, and create a new nonterminal in each rule.
 - In the above rule we might define DList to be represented as

```
public class DList{
    public String trans;
}
```
 - For ASTs: when we execute an SDT rule, we construct a new node object for the RHS, and propagate its fields with the fields of the LHS nodes

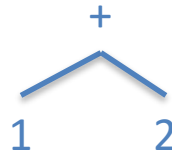
Thinking about implementing ASTs

- Consider the AST for a simple language of Expressions

Input
1 + 2

Tokenization
intlrit plus intlrit

AST

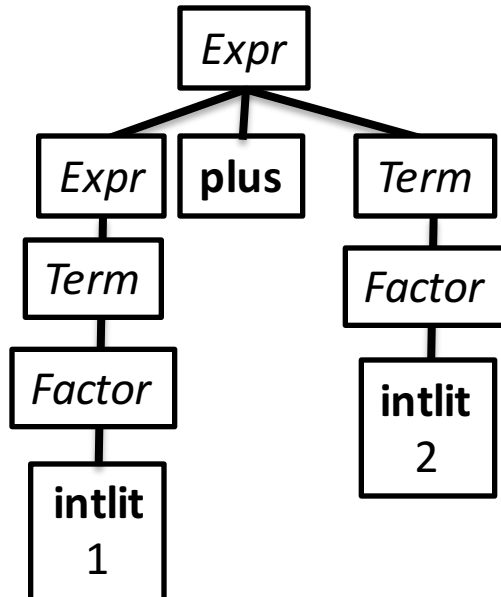


Naïve AST Implementation

```
class PlusNode
    IntNode left;
    IntNode right;
}
```

```
class IntNode{
    int value;
}
```

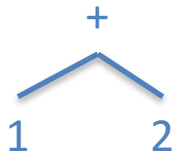
Parse Tree



Thinking about implementing ASTs

- Consider AST node classes
 - We'd like the classes to have a common inheritance tree

AST

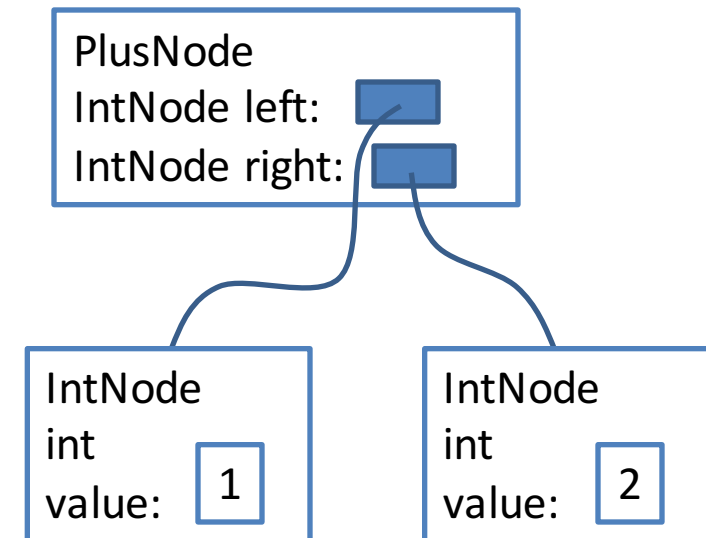


Naïve AST Implementation

```
class PlusNode
{
    IntNode left;
    IntNode right;
}
```

```
class IntNode
{
    int value;
}
```

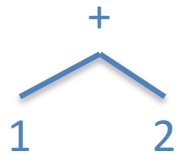
Naïve java AST



Thinking about implementing ASTs

- Consider AST node classes
 - We'd like the classes to have a common inheritance tree

AST



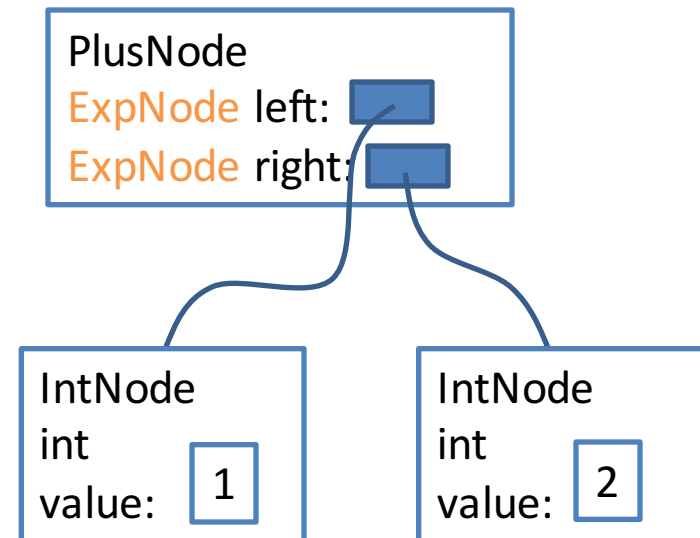
Naïve AST Implementation

```
class PlusNode
{
    IntNode left;
    IntNode right;
}
```

```
class IntNode
{
    int value;
}
```

Make these extend
ExpNode

Better java AST



Implementing ASTs for Expressions

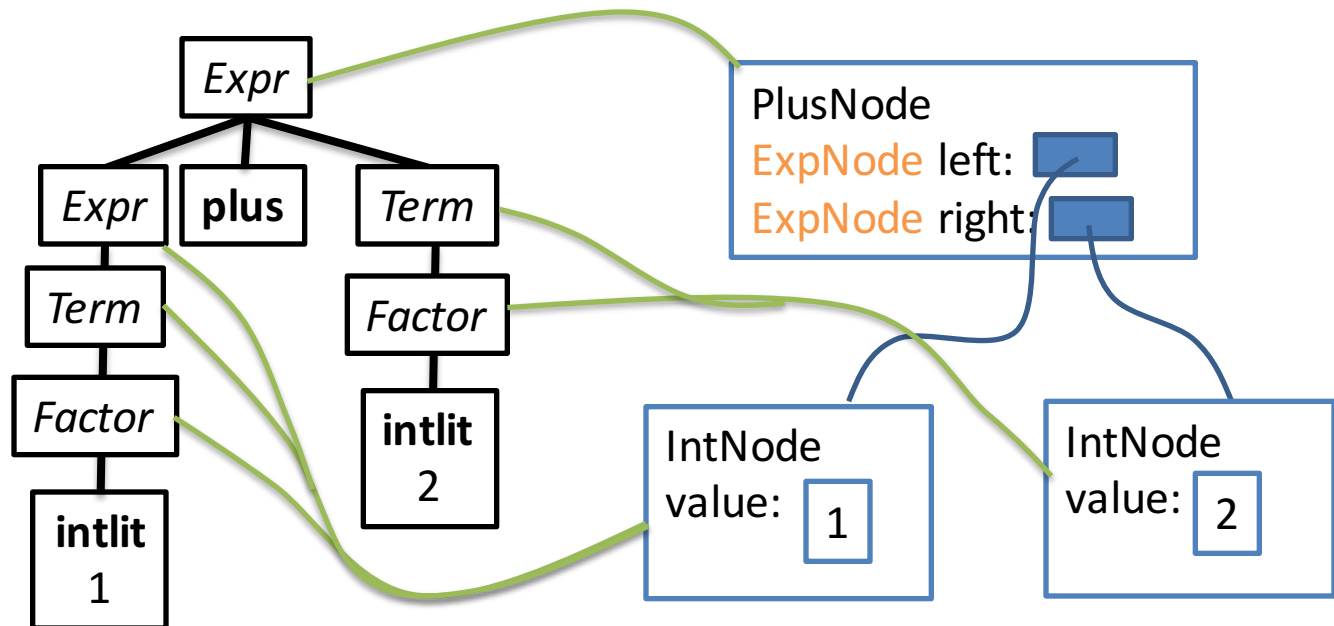
CFG

Expr \rightarrow Expr + Term
| Term
Term \rightarrow Term * Factor
| Factor
Factor \rightarrow intlit
| (Expr)

Translation Rules

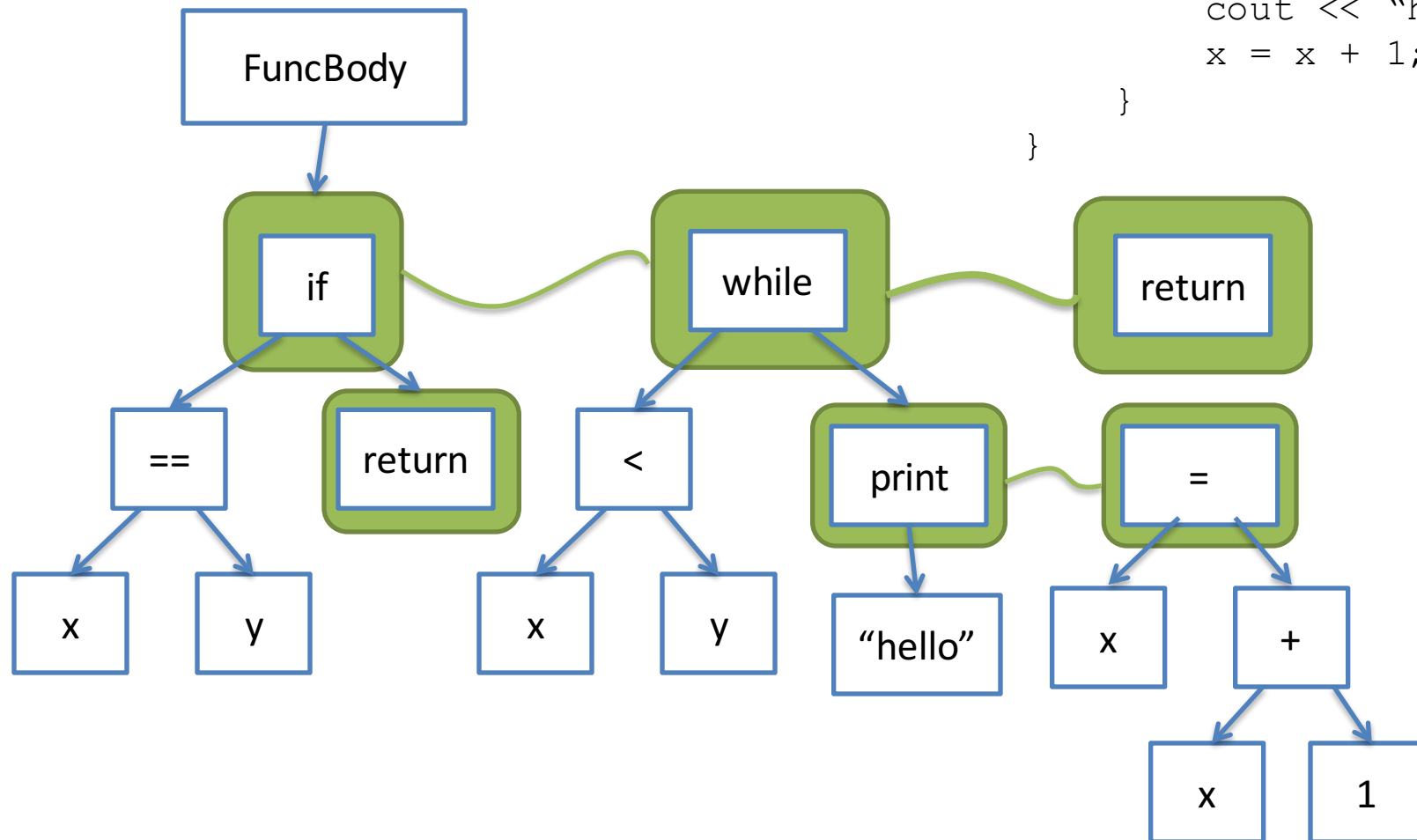
$Expr1.trans = \text{new PlusNode}(Expr2.trans, Term.trans)$
 $Expr.trans = Term.trans$
 $Term1.trans = \text{new TimesNode}(Term2.trans, Factor.trans)$
 $Term.trans = Factor.trans$
 $Factor.trans = \text{new IntNode}(\text{intlit.value})$
 $Factor.trans = Expr.trans$

Example: 1 + 2



An AST for a YES Snippet

```
void foo(int x, int y){  
    if (x == y){  
        return;  
    }  
    while ( x < y){  
        cout << "hello";  
        x = x + 1;  
    }  
}
```



Summary (1 of 2)

- Today we learned about
 - Syntax-Directed Translation (SDT)
 - Consumes a parse tree with actions
 - Actions yield some result
 - Abstract Syntax Trees (ASTs)
 - The result of SDT for parsing in a compiler
 - Some practical examples of ASTs

Summary (2 of 2)

Scanner

Language abstraction: RegEx

Output: Token Stream

Tool: JLex

Implementation: DFA walking via table

Parser

Language abstraction: CFG

Output: AST by way of Parse Tree

Tool: Java CUP

Implementation: ???

Next week

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