Plan for Today

Logistics

- Recitation on Friday will be a review for Final Exam.
  - Review notes will be posted Wednesday night.
  - People can ask questions during recitation and/or on Piazza. Example questions with answers will receive extra credit as per syllabus.
- PA5 is due Monday. Any questions?
- PA4 Peer Review summary

Reviewing compilation covered by other professors

- (See slides on schedule or notes posted in piazza)
- LR parsing: performs a right-most derivation in reverse
- Symbol tables and scope
- Register allocation for expression trees

PA4 Peer Reviews

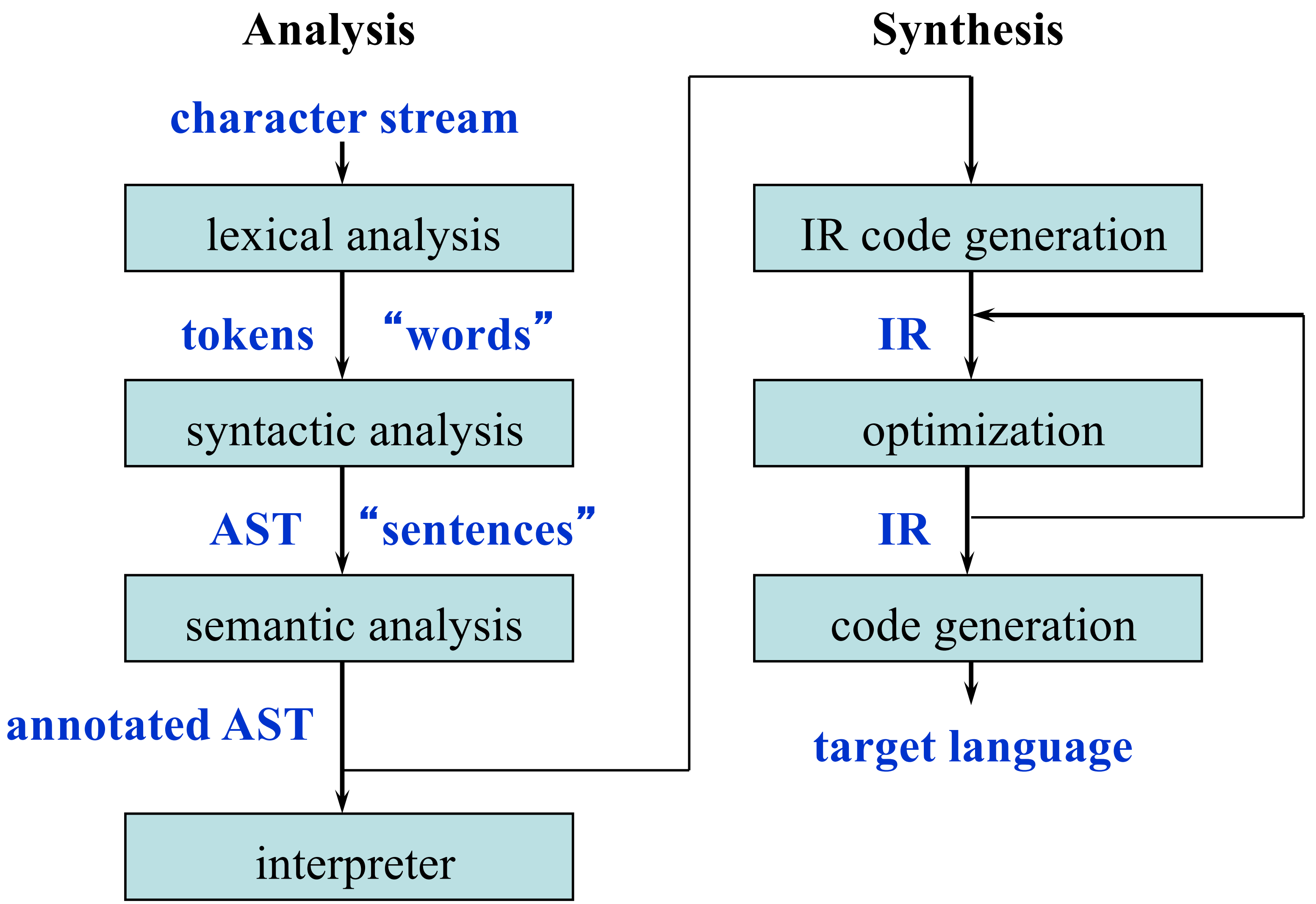
Specific Comments that are Useful

- "This is the cleanest compiler assignment my eyes have ever seen" …"I especially appreciated the symbol table pretty print functions, the massive amount of Java keywords that can be lexed, and the optional arguments in main for testing purposes."Coding structure to emulate
- "Reformatting the token row/col information to be stored in a token wrapper rather than the token itself may have made the parser much easier to understand and write. This means we wouldn't have had to pass the new int arguments around and handle them in multiple cases."

Fun jokes in README

- "I like my steak how I like my transformers. Optimus prime."
- "A manager, a mechanical engineer, and software analyst are driving back from convention through the mountains. Suddenly, as they crest a hill, the brakes on the car go out and they fly careening down the mountain. After scraping against numerous guardrails, they come to a stop in the ditch. Everyone gets out of the car to assess the damage. The manager says, "Let's form a group to collaborate ideas on how we can solve this issue."
  The mechanical engineer suggests, "We should disassemble the car and analyze each part for failure." The software analyst says, "Let's push it back up the hill and see if it does it again."

Structure of a Typical Compiler



LL vs LR Parsing

LL(k) must predict which production looking ahead k:

$S \rightarrow SS \mid (S) \mid \varepsilon$

is it $S \rightarrow SS$ or (S) when I see ((((……. ?

produces the parse tree TOP DOWN, with a left to right derivation

LR(k) postpones the decision until all tokens of the rhs of a grammar production plus k more tokens have been seen. It therefore is more powerful.

It does this by parsing BOTTOM UP

Example LR parse

S → AB   A → Aa | a   B → Bb | b   S' → S $

aaabb$ ← **A** **a** abb$ ← **A** **a** bb$ ← A **b** b$ ← A B b$ ← **AB** $ ← **S$** ← S'

Notice that this is the rightmost derivation

S' → S$ → AB$ → ABb$ → Abb$ → Aabb$ → Aaabb$ → aaabb$

in reverse!

It does not start with the start symbol, it ends with it

LR(k) parsing scans the input Left to right and produces the Rightmost derivation (looking k tokens ahead) in reverse.

Simplified example LR parsing engine actions

S → AB   A→ Aa | a   B → Bb | b   S' → S $

Stack	input	action
	aaabb$	shift
a	aabb$	reduce : A→a
A	aabb$	shift
Aa	abb$	reduce: A→Aa
A	abb$	shift
Aa	bb$	reduce: A→Aa
A	bb$	shift
Ab	b$	reduce: B→b
AB	b$	shift
ABb	$	reduce: B→Bb
AB	$	reduce: S→AB
S	$	accept

Shift reduce parsing applied to unambiguous grammars

```
[0] S  →  ( S )
[1] S‘ →  S $
[2] S  →  ID
```

Single parentheses nest

Start symbol is S’

Stack	input	action
	((ID))$	shift
(	(ID))$	shift
((	ID))$	shift
((ID	))$	reduce: S→Id
((S	))$	shift
((S)	)$	reduce: S→(S)
(S	)$	shift
(S)	$	reduce: S→(S)
S	$	accept

Static Scope Rules

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Most languages have static scope rules

- **Static scope rules are based on the program text**
  - The scope of a declaration can be determined at compile time
  - Otherwise, the language is said to have dynamic scope rules
  - Macro-expansion results in dynamic scope
- **A block consists of declarations and statements**
  - Blocks are delimited by braces, `{}`, in C, Java, …
  - Blocks can be nested
  - Does MeggyJava have blocks?

Scope of a Declaration

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How many declarations of `x`?

```
class C
{
    int x;
    public int f(int x)
    {
        return x;
    }
    public int g(int y)
    {
        return x;
    }
}
```

Scope of a Declaration

Subscripts distinguish between roles of `x`

```
class C
    {
        int x1;
        public int f(int x2)
        {
            return x2;
        }
        public int g(int y)
        {
            return x1;
        }
    }
```

Block B_1 (the class body, from `{` to `}`)

Block B_2 (the body of `f`)

Block B_3 (the body of `g`)

Hole in the Scope of a Declaration

University of Arizona, Computer Science

Block B_2 is a hole in the scope of the declaration of $\mathbf{x}_1$

```
class C
    {
        int x_1;
        public int f(int x_2)
        {
            return x_2;
        }
        public int g(int y)
        {
            return x_1;
        }
    }
```

Block B_1 (the outer braces of class C)

Block B_2 (the body of f)

Block B_3 (the body of g)

Most Closely Nested Rule

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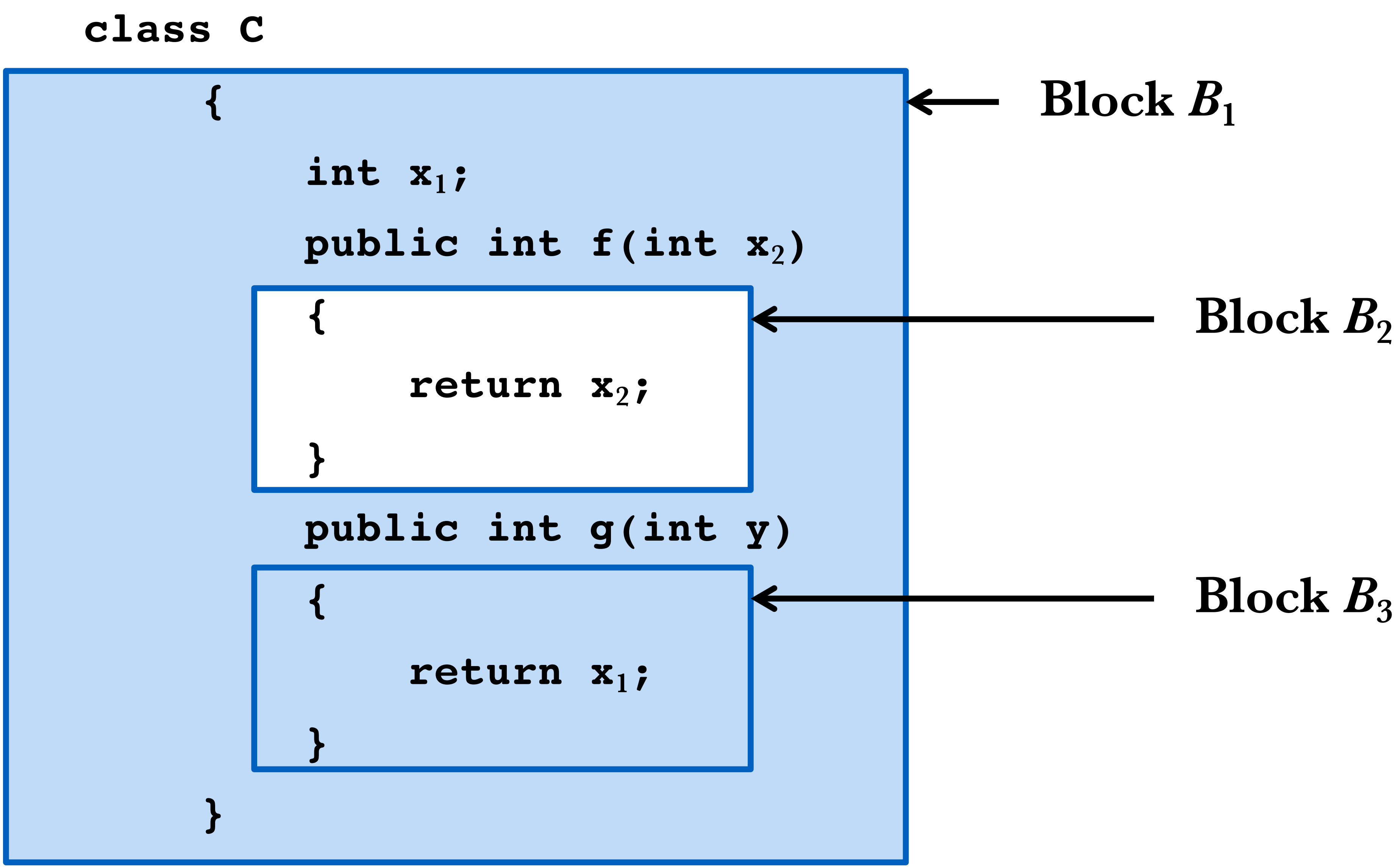
Find the declaration of **`x`** by examining blocks inside out



Symbols

What do the occurrences of `x` denote?

```
class Foo {
    public static void main(String[] s) {
        new E().f(3); }
class E {
    C x;
    public int f(int y) {
        C x; x = new C(); x.x = 7;
        this.initE();
        return x.x;
    }
    public C initE() { x=new C(); x.x = 9; return x; }
}
```

Expression Evaluation

Sethi-Ullman Register allocation

```
label(node)
    if node is leaf then node.label = 1
    else if node is binary
        if node.left.label == node.right.label
        then node.label = node.left.label + 1
    else
        node.label = max( node.left.label,
        nodel.right.label )
    else if node is unary
        node.label = node.child.label
```

Questions to understand how to answer

- How many registers are needed if not using memory (aka push/pop)?
- Order of evaluation to make this register count work?
- What if an operator has more than 2 operands?