Parser Output

- So far, our parser simply returns when there has been a successful parse
  - Need to make it generate an output – an Abstract Syntax Tree (AST).
- We don't actually *need* to do this
  - We can place all our semantic analysis, code generation etc. in the parser code itself
  - This is not necessarily a good idea
    - Less modular
    - More error prone
- The AST is the central data structure of our compiler
  - The parser builds it
  - The remaining phases annotate it and re-arrange it (perhaps)
- The rest of the compiler is a series of modules that simply *walk* the AST, performing their intended tasks.
  - Time to review your Data-Structures lectures!

 ©2004 Kevin J. Maciunas, Robert Esser, Charles Lakos

AST - Description

- There is no "built-in" meaning to the AST
  - Each compiler we build will have a unique kind of parse tree
- Example Pascal program:

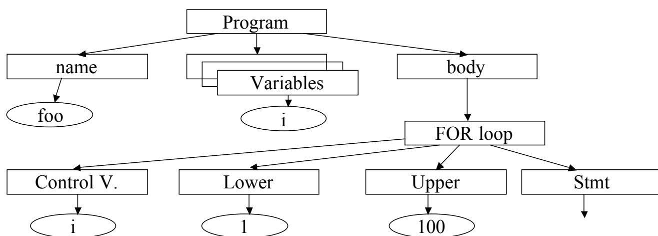
```
program foo(output);
var I : integer;
begin
  for I = 1 to 100 do
    writeln(I);
end .
```

- Our parse trees will be extremely simple: we will build a child tree for each syntactic element as we find it, left-to-right.

 ©2004 Kevin J. Maciunas, Robert Esser, Charles Lakos

Tree View

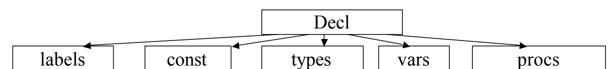
```
program foo(output);
var i : integer;
begin
  for i = 1 to 100 do
    writeln(i);
end .
```



 ©2004 Kevin J. Maciunas, Robert Esser, Charles Lakos

This is *not* a Binary Tree!

- For each of the non-terminals in the language, we need to invent a node structure in the AST
- Pascal's declarative region allows you to declare (in this order alone): labels, constants, types, variables and procedures/functions.
- We simply build an AST node that does precisely this:



- Within each of these categories, we simply build more nodes
- So if we have 10 variables, we have 10 children of the "vars" node…

 ©2004 Kevin J. Maciunas, Robert Esser, Charles Lakos

Our AST

- We will make use of a *simple* AST

```
public interface ASTNode {

  // return an Iterator on all the children of this node
  public Iterator childIterator();

  // Adds a child to the list of children
  // This method also sets parent of child
  public void addChild(ASTNode child);

  // Removes the child from the list of children
  // This method also sets parent of child to be null
  public void removeChild(ASTNode node)
    throws ASTNodeNotFoundException;

  …
```

 ©2004 Kevin J. Maciunas, Robert Esser, Charles Lakos

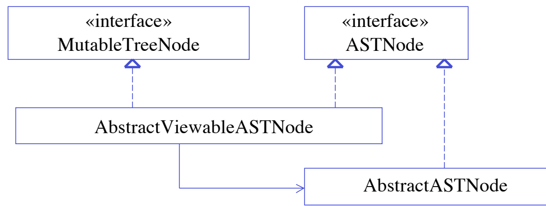
Our AST

- We will make use of a *simple* AST

```
public interface ASTNode {
  …

  // returns the number of children
  public int numChildren();

  // returns the parent node or null if this node is a root node
  public ASTNode currentParent();

  // sets the parent of this node
  public void newParent(ASTNode parent);

  // returns information on what the node represents
  public String toString();
}
```

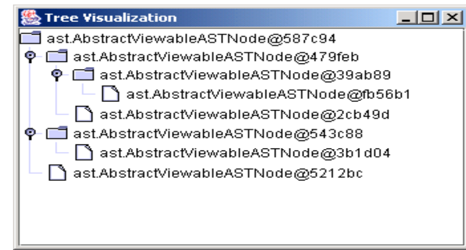
 ©2004 Kevin J. Maciunas, Robert Esser, Charles Lakos

AST Infrastructure



- Implementors of *MutableTreeNode* can be rendered in a *JTree*
- You must extend either *AbstractViewableASTNode* or *AbstractASTNode* for every node type you define
- Suggestion: for your parser derive your AST nodes from *AbstractViewableASTNode*
  - Easier to debug
  - Only slightly less efficient

Viewing an AST



- The above figure shows the resulting window after invoking the main method in *AbstractViewableASTNode*
- In all *ASTNode* implementations write a suitable *toString()* method
  - this text will appear in the tree view
  - an ideal debugging tool for your parser and AST!

Parse Tree HOW-TO

- For each syntactic category, decide how you'll lay out the tree
  - Decide what information needs to be stored in each node
  - Think clearly, draw the picture, make sure ***all*** the information you'll need is in there
- Build a concrete implementation that conforms to the interface.
- Program defensively
  - if you expect only *n* child nodes then test this assertion
- Annotate the syntax specification with *tree building notes*
  - Remember: there is a 1:1 mapping between the syntax and the parser code
- In the parser code, insert the necessary tree building code.
- After calling the parser, it should yield a parse tree
- Note well – this is an *Abstract* syntax tree
  - It does **not** contain terminal symbols (that can be deduced)
  - It will only contain terminal symbols like identifiers

Parse Tree infrastructure

- You will need to write a *node class* for each programming language construct
  - There will be many classes, but all will be very simple
  - This is object-oriented programming!
- You will need to implement (override) several methods in this class, but we will flesh those details in later
  - Always use a standard interface e.g. *ASTNode*
- Start with a pretty print method for each syntactic category
  - E.g. a Pascal *while* loop class might have a *prettyPrint()* method that:
    - Prints the keyword "while"
    - Invokes the *prettyPrint()* method for the boolean valued expression that controls the loop
    - Prints the keyword "do"
    - Skips to a new line, invokes *prettyPrint()* on the statement list that is the body…
  - Note that you need to pass the *prettyPrint()* method the current indentation level

Example

```
public void prettyPrint(int currentIndent) {
/* Pretty Prints the While loop like so:
     while <expr> do
       statement;
     I.e. : body is indented two spaces…
*/
 …
 for(i=0; i<currentIndent;i++){
   System.out.print(' ');
 };
 //we must have exactly 2 child nodes
 Utility.assert(numChildren() == 2);
 Iterator iterator = childIterator();
 System.out.print("while ");
 ((Expression)(iterator.next()).prettyPrint();
 System.out.println("do");
 ((Statement))(iterator.next()).
     prettyPrint(currentIndent + 2);
};
```