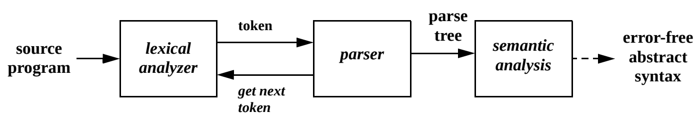
Compiler Front-End

- *Almost all compilers and interpreters contain the same **front-end** --- it consists of three components:*

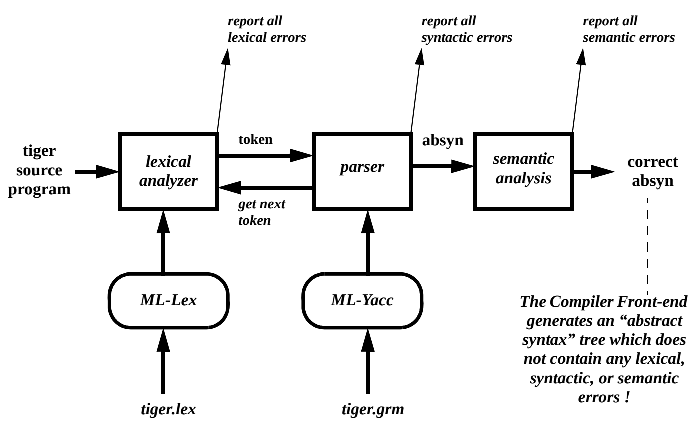
  1. **Lexical Analysis** --- report lexical errors, output a list of tokens
  2. **Syntax Analysis** --- report syntactic errors, output a parse tree
  3. **Semantic Analysis** --- report semantic errors (e.g., type-errors, undefined identifiers, ...) --- generate a clean and error-free "*abstract syntax tree*"



"Concrete" vs. "Abstract" Syntax

- *The grammar specified in "`tiger.grm`" (for Yacc) is mainly used for parsing only ---------- the key is to resolve all ambiguities. This grammar is called **Concrete Syntax**.*
- ***Abstract Syntax** (**Absyn**) is used to characterize the essential structure of the program ----------- the key is to be as simple as possible; **Absyn** may contain ambiguities.*
- *The grammar for **Abstract Syntax** is defined using ML **datatypes.***
- ***Traditional Compilers:** do semantic analysis on Concrete Syntax --- implemented as "actions" in Section 3 of "`tiger.grm`" file (for Yacc)*
- ***Modern Compilers**: "`tiger.grm`" constructs the Abstract Syntax tree; the semantic analysis is performed on the Absyn later after parsing!*

Tiger Compiler Front End



Tiger Program and Expression

- *A Tiger program* `prog` *is just an expression* `exp`
- *An expression can be any of the following:*

l-value	`foo, foo.bar, foo[1]`
Nil	`nil`
Integer literal	`34`
String literal	`"Hello, World\n"`
Sequencing	`(exp; exp; ...; exp)`
Function call	`id(), id(exp{,exp})`
Arithmetic expression	`exp arith-op exp`
Comparison expression	`exp comp-op exp`
Boolean operators	`exp & exp, exp | exp`
Record creation	`ty-id {id = exp, ...}, {}`
Array creation	ty-id [exp_1] of exp_2
Assignment	`lvalue := exp`

Tiger Expression and Declaration

- *More Tiger expressions:*

If-then-else	**if** exp$_1$ **then** exp$_2$ **else** exp$_3$
If-then	**if** exp$_1$ **then** exp$_2$
While-expression	**while** exp$_1$ **do** exp$_2$
For-expression	**for** id:=exp$_1$ **to** exp$_2$ **do** exp$_3$
Break-expression	**break**
Let-expression	**let** decsq **in** {exp} **end**

- *A Tiger declaration sequence is a sequence of type, variable, and function declarations:*

dec -> *tydec* | *vardec* | *fundec*
decsq -> *decsq dec* | ε

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Tiger Type Declaration

- *Tiger Type declarations:*

tydec -> **type** *id* = *ty*

ty -> *id* | **{** *tyfields* **}** | **array of** *id*

tyfields -> ε | *id* : *type-id* {,*id*: *type-id*}

- *You can define mutually-recursive types using a* ***consecutive sequence*** *of type declarations*

```
type tree = {key : int, children : treelist}
type treelist = {hd : tree, tl : treelist}
```

recursion cycle must pass through a record or array type !

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Variable and Function Declaration

- *Tiger Variable declarations:*

short-form: *vardec* -> **var** *id* := *exp*
long-form: *vardec* -> **var** *id* : *type-id* := *exp*

"var x := 3**"** in Tiger is equivalent to **"val** x = **ref** 3**"** in ML

- *Tiger Function declarations:*

procedure: *fundec* -> **function** *id* **(***tyfields***)** := *exp*
function:
fundec -> **function** *id* **(***tyfields***)**:*type-id* := *exp*

- *Function declarations may be mutually recursive --- must be declared in a* ***sequence*** *of* ***consecutive*** *function declarations! Variable declarations* ***cannot*** *be mutually recursive !*

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Tiger Absyn "Hack"

- *When translating from* ***Concrete Syntax*** *to* ***Abstract Syntax,*** *we can do certain syntactic transformations*

MINUS *exp* ===> 0 **MINUS** *exp*

exp$_1$ **&** *exp*$_2$ ===> **if** *exp*$_1$ **then** *exp*$_2$ **else** *0*

exp$_1$ **|** *exp*$_2$ ===> **if** *exp*$_1$ **then** *1* **else** *exp*$_2$

This can make **Abstract Syntax** even simpler.

Toy does not support Macros. If the source language supports macros, they can be processed here.

Tiger Semantics

- **`nil`** **---** *a value belong to every record type.*
- *Scope rule --- similar to PASCAL, Algol ---- support nested scope for types, variables, and functions; redeclaration will hide the same name.*

```
function f(v : int) =
  let var v := 6
   in print(v);
      let var v := 7 in print(v) end;
      print(v);
      let var v := 8 in print(v) end;
      print(v)
  end
```

- *Support two different* ***name space:*** *one for types, and one for functions and variables. You can have a type called* `foo` *and a variable* `foo` *in scope at same time.*

An Example

```
(* A program to solve the 8-queens problem, see Appel's book *)

let
    var N := 8

    type intArray = array of int
    var row := intArray [ N ] of 0
    var col := intArray [ N ] of 0
    var diag1 := intArray [N+N-1] of 0
    var diag2 := intArray [N+N-1] of 0

    function printboard() =
       (for i := 0 to N-1
        do (for j := 0 to N-1
            do print(if col[i]=j then " O" else " .");
            print("\n"));
        print("\n"))

    function try(c:int) =
      (* for i:= 0 to c do print("."); print("\n"); flush(); *)
      if c=N then printboard()
      else for r := 0 to N-1
           do if row[r]=0 & diag1[r+c]=0 & diag2[r+7-c]=0
              then (row[r]:=1; diag1[r+c]:=1; diag2[r+7-c]:=1;
                    col[c]:=r; try(c+1);
                    row[r]:=0; diag1[r+c]:=0; diag2[r+7-c]:=0)

 in try(0)
end
```