Data Layouts

Data Structures For a Simple Compiler

Symbol Tables

Information about user defined names

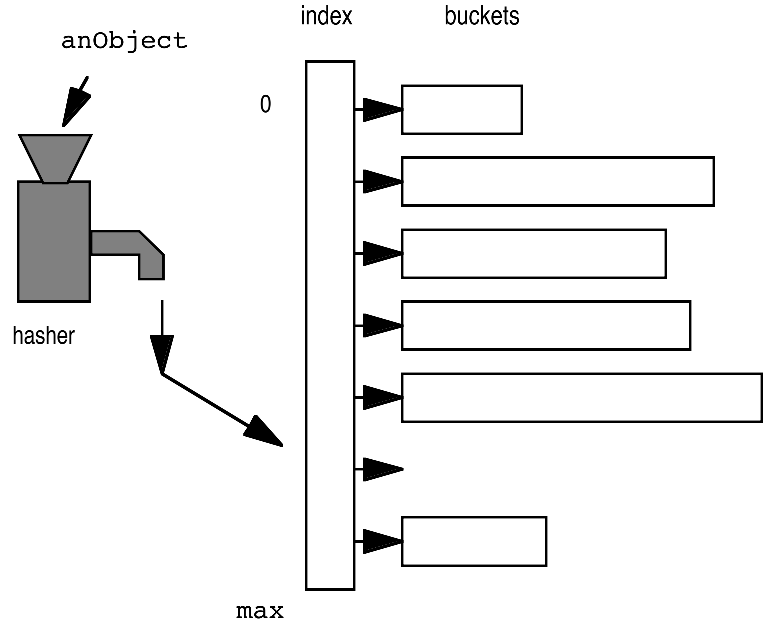
Symbol Table

- Symbol Tables are organized for fast lookup.
  - » Items are typically entered once and then looked up several times.
  - » Hash Tables and Balanced Binary Search Trees are commonly used.
  - » Each record contains a “name” (symbol) and information describing it.

Simple Hash Table

- Hasher translates “name” into an integer in a fixed range- the hash value.
- Hash Value indexes into an array of lists.
  - » Entry with that symbol is in that list or is not stored at all.
  - » Items with same hash value = bucket.

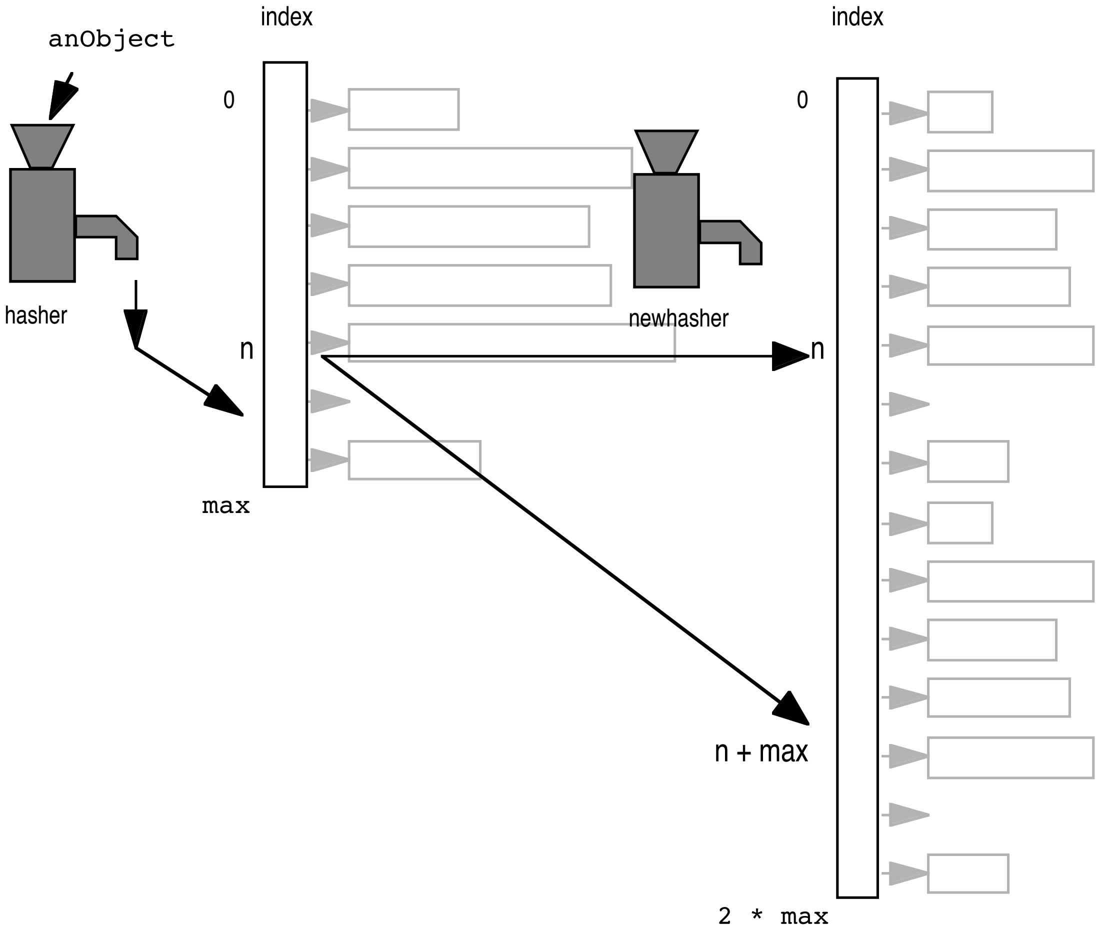
Simple Hash Table



Self Organizing Hash Table

- Can achieve constant average time lookup if buckets have bounded average length.
- Can guarantee this if we periodically double number of hash buckets and re-hash all elements.
  - » Can be done so as to minimize movement of items.

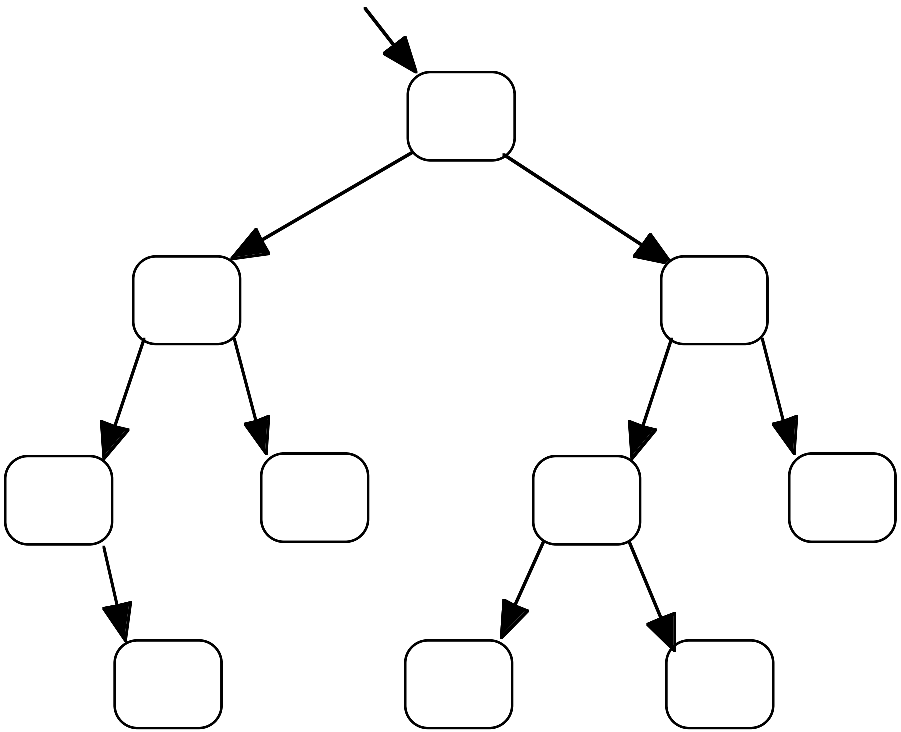
Self Organizing Hash Table



Balanced Binary Search Tree

- Binary search trees work if they are kept balanced.
- Can achieve logarithmic lookup time.
- Algorithms are somewhat complex.
  - » Red-black trees and AVL trees are used.
  - » No leaf is much farther from root than any other

Balanced Binary Search Tree



Symbol Tables + Blocks

- If a language is block structured then each block (scope) needs to be represented separately in the symbol table.
- If the hash table buckets are “stack-like” this is automatic.
- Can use a stack of balanced trees with one entry per scope.

Special Cases

- Some languages partition names into different classes- keywords, variable&function names, struct names...
- Separate symbol tables can then be used for each kind of name. The different symbol tables might have different characteristics.
  - » hashtable-sortedlist-binarytree...

Parsing Information

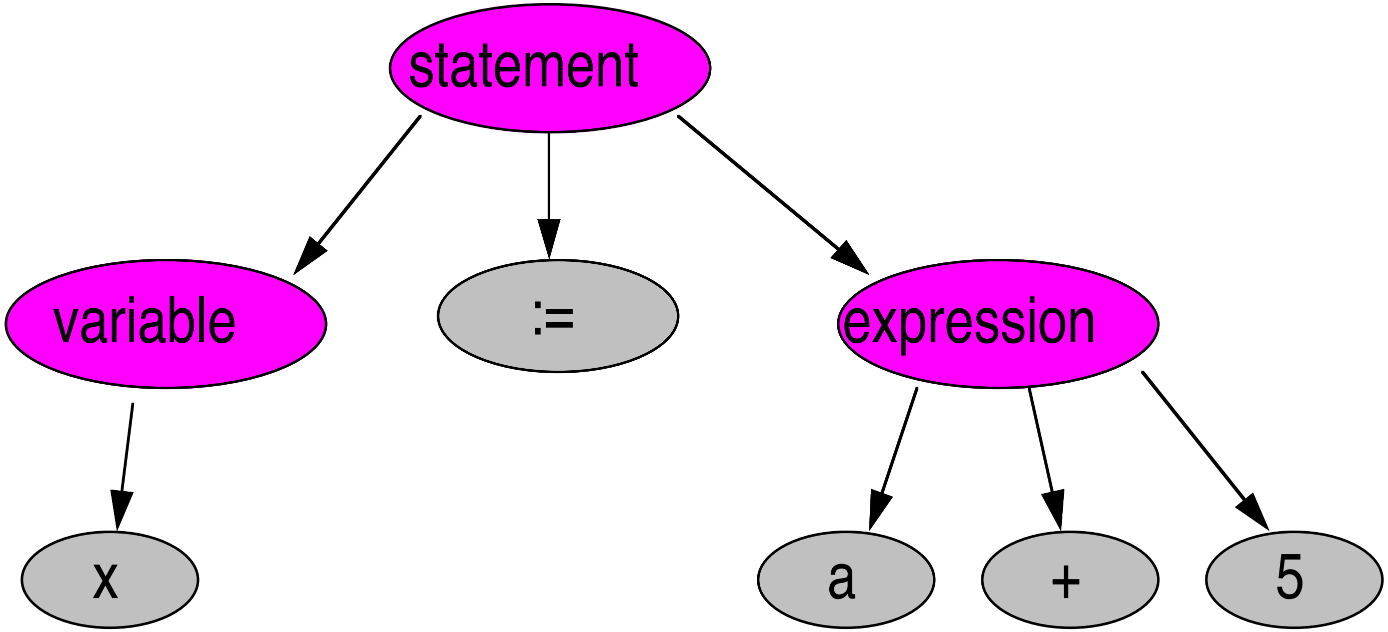
Parse Trees

- The structure of a modern computer language is tree-like
- Trees represent recursion well.
- A gramatical structure is a node with its parts as child nodes.
- Interior nodes are nonterminals.
- The tokens of the language are leaves.

Parse Trees

<statement> ::= <variable> “:=“ <expression>

x := a + 5



Parse Trees

- There are different node types in the same tree.
- Variant records or type unions are typically used. Object-orientation is also useful here.
- Each node has a tag that distinguishes it, permitting testing on node type.

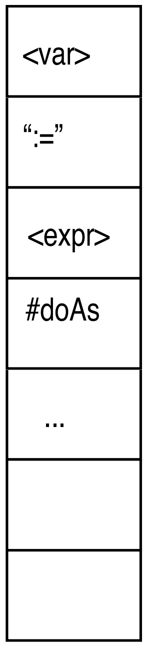
Parse Stack

- Parsing is often accomplished with a stack. (Not in this version of GCL)
- The stack holds values representing tokens, nonterminals and semantic symbols from the grammar.
  - It can either hold what is expected next (LL parsing) or what has already been seen (LR parsing)

Parse Stack

- A stack is used because most languages and their grammars are recursive. Stacks can accomplish much of what trees can.
- The contents of the stack are usually numeric encodings of the symbols for compactness of representation and speed of processing.

Parse Stack



G rammar fragment

<statement> ::= <variable> “:=” <expression> #doAssign

Example being scanned:

max := max + 1;

Stack vs Parameters

- In recursive descent parsing, no stack is needed.
- This is because the semantic records can be passed directly to the semantic routines as parameters.
- Semantic records can also be returned from the parsing functions.

Tokens

Information produced by the Scanner

Token Records

- Token records pass information about symbols scanned. This varies by token type.
- Variant records or type unions are typically used.
- Each value contains a tag - the token type - and additional information.
  - The tag is usually an integer.

Token Examples

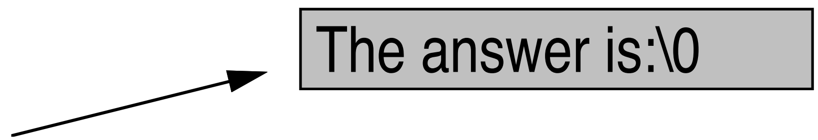
- Simple tokens
- No additional info
- Only the tag field
  - » endNum
- Others are more complex
- Tag plus other info
  - » numeralNum
  - » 35

Handling Strings

- Strings are variable length and therefore present some problems.
- In C we can allocate a free-store object to hold the spelling--BUT, allocation is expensive in time.
- In Pascal, allocating fixed length strings is wasteful.
- Spell buffers are an alternative.

Strings in the Free Store

write "The answer is: ", x;



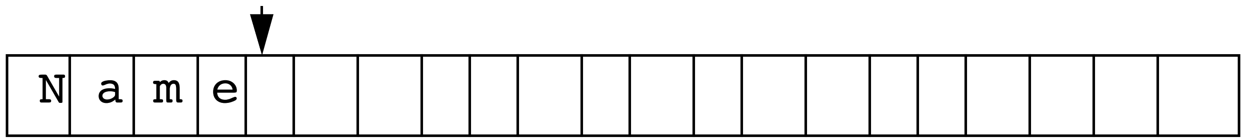
strval = new char[16];

The string is represented by the value of the pointer which can be passed around the compiler.

Strings in a Spell Buffer

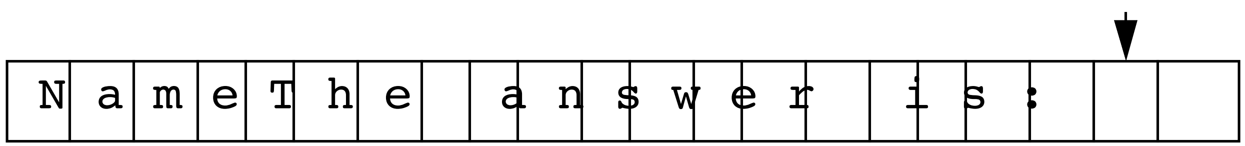
write “The answer is: “, x;

3



before

18



after

The string is represented as (3,15) = (start, length)

Semantic Information

Semantic Information

- Parsing and semantic routines need to share information.
- This information can be passed as function parameters or a semantic stack can be used.
- There are different kinds of semantic information.
  - » Variant Records/Type Unions/Objects

Semantic Records

- Each record needs a tag to distinguish its kind. We need to test the tag types.
- Depending on the tag there will be additional information.
- Sometimes the additional information must itself be a tagged union/variant record.

Simple Semantic Records

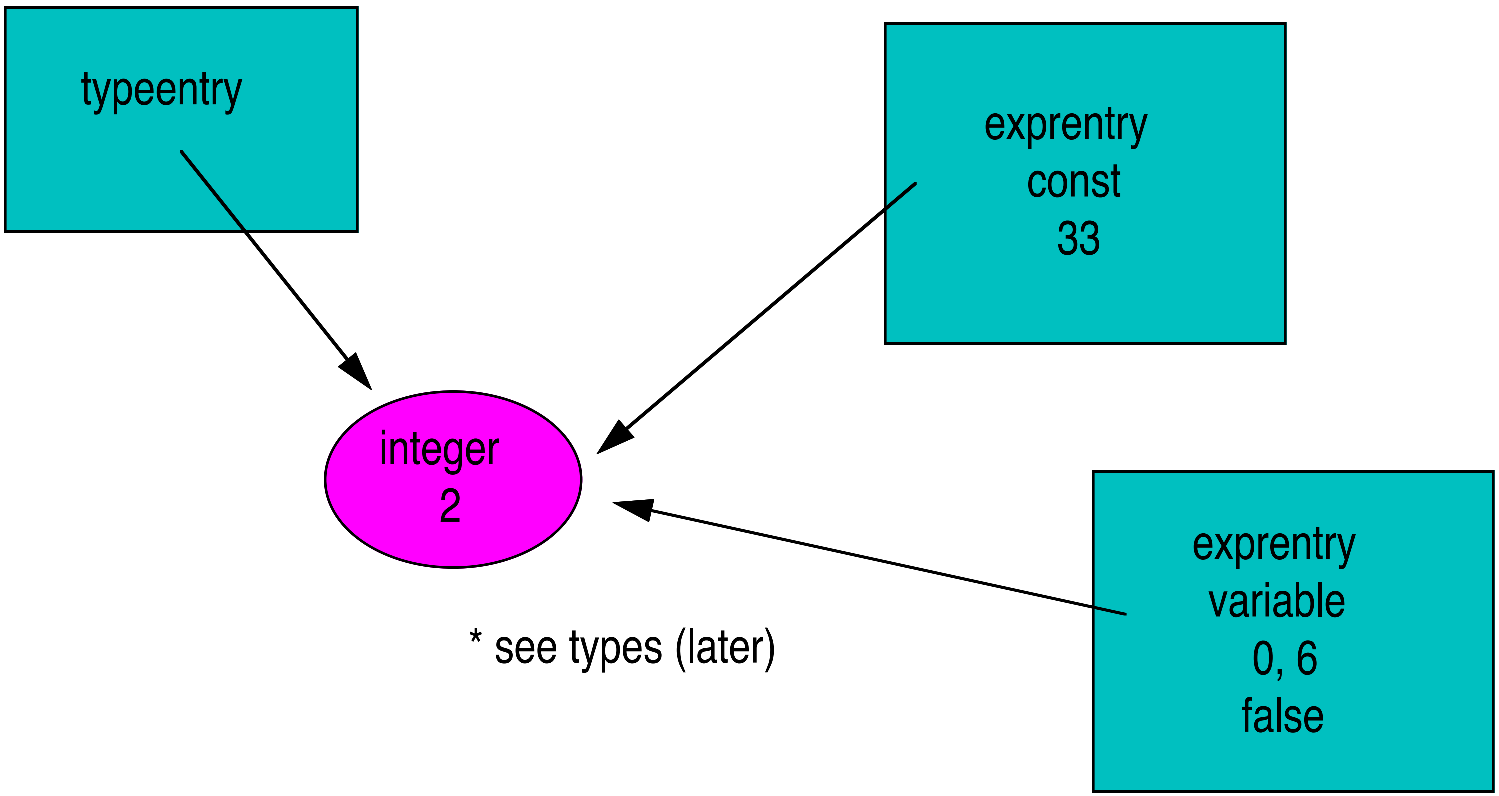
identifier
maximum
7

addoperator
+

reloperator
<=

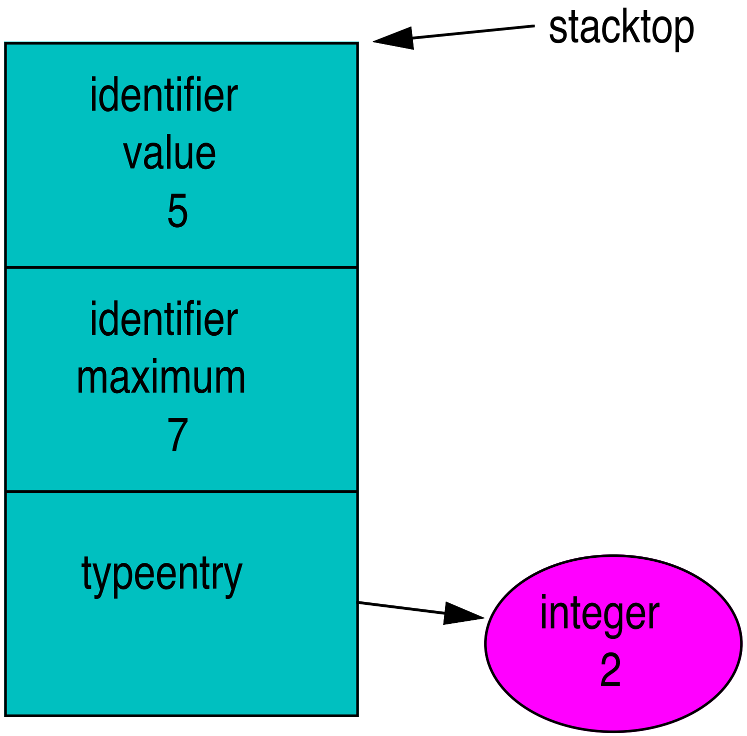
ifentry
J35
J36

Complex Semantic Records



* see types (later)

Semantic Stack



In some compilers semantic records are stored in a semantic stack. In others, they are passed as parameters.

Type Information

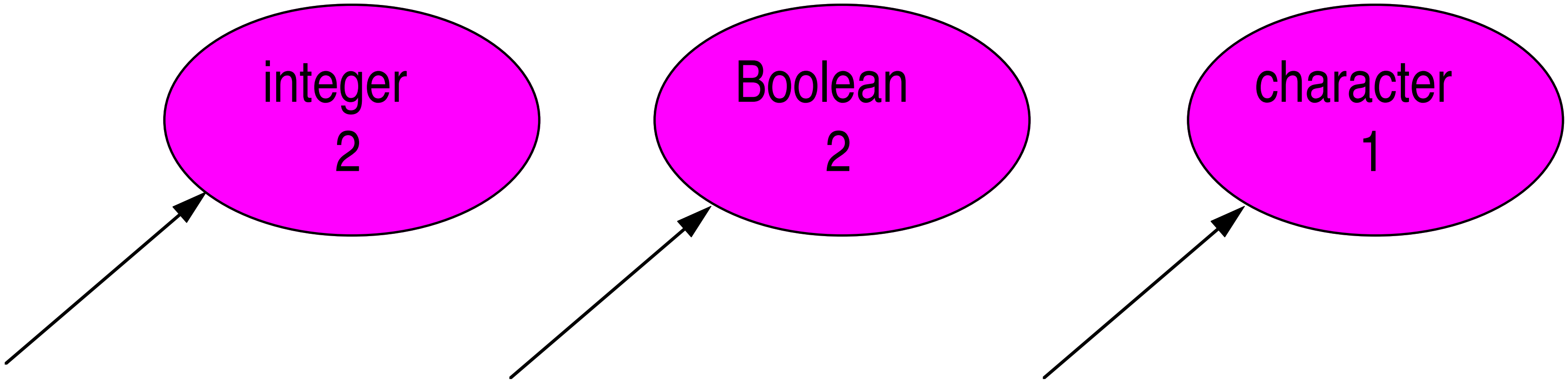
Type Information

- Type information must be maintained for variables and parameters.
- There are different kinds of types
  - » Variant Records/Type Unions/Objects
- There are different typing rules in different languages.
  - » Pointers to records/structs are a simple representation.

Type Information

- Types describe variables.
  - » size of a variable of this type(in bytes)
  - » kind (tag)
  - » additional information for some types.
- There are also recursive types.

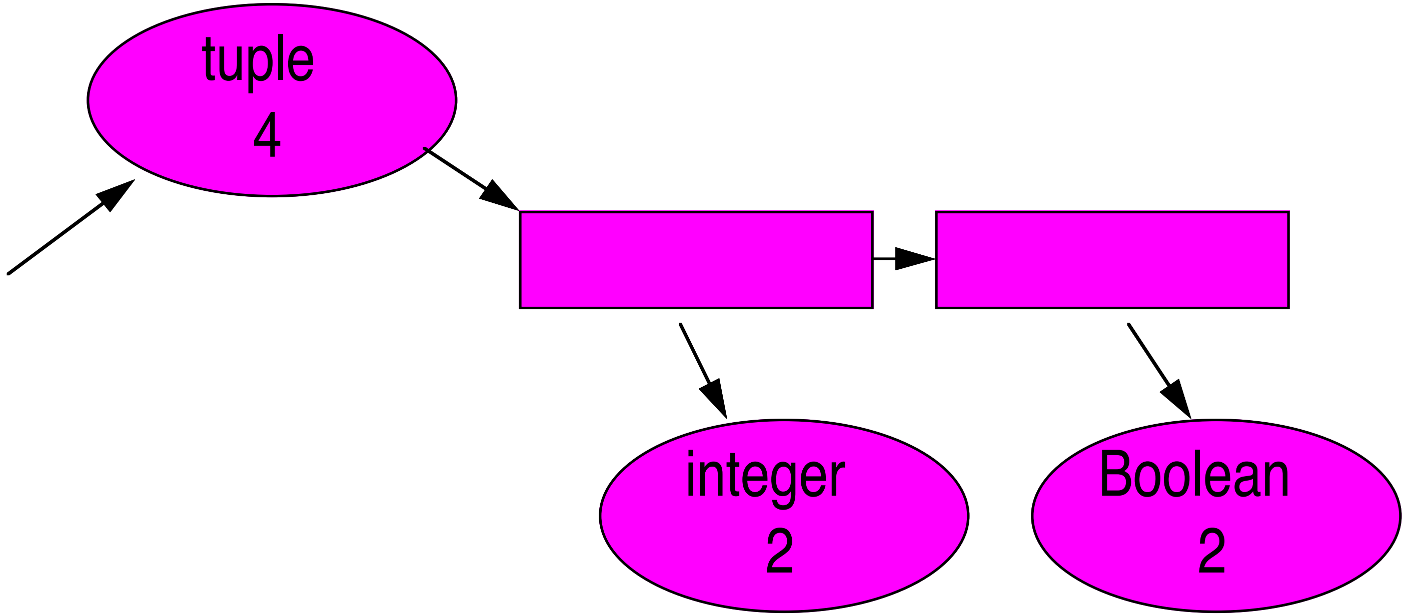
Simple Types



The tag and the size are enough.

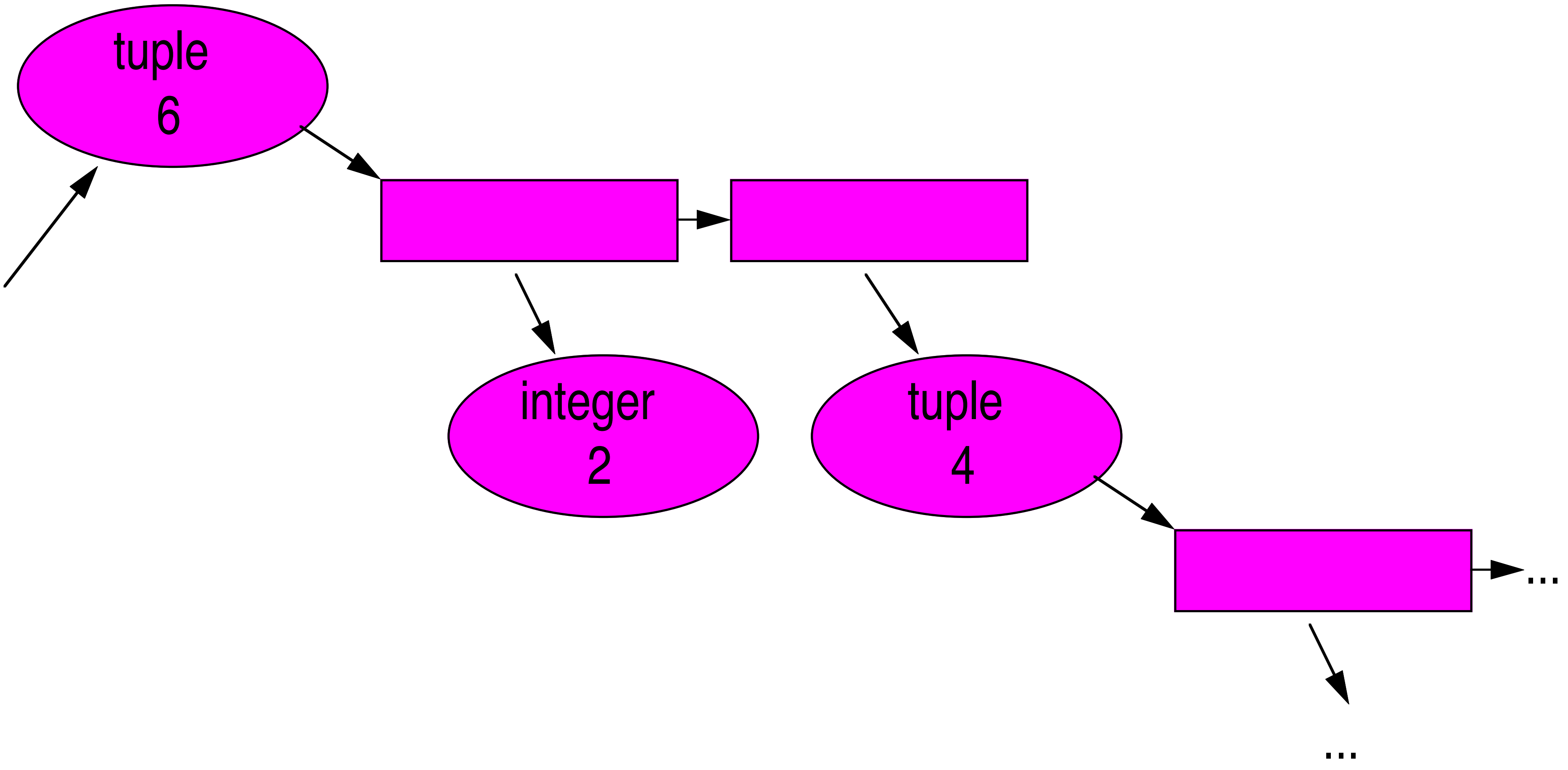
Tuple Type

[integer, Boolean]



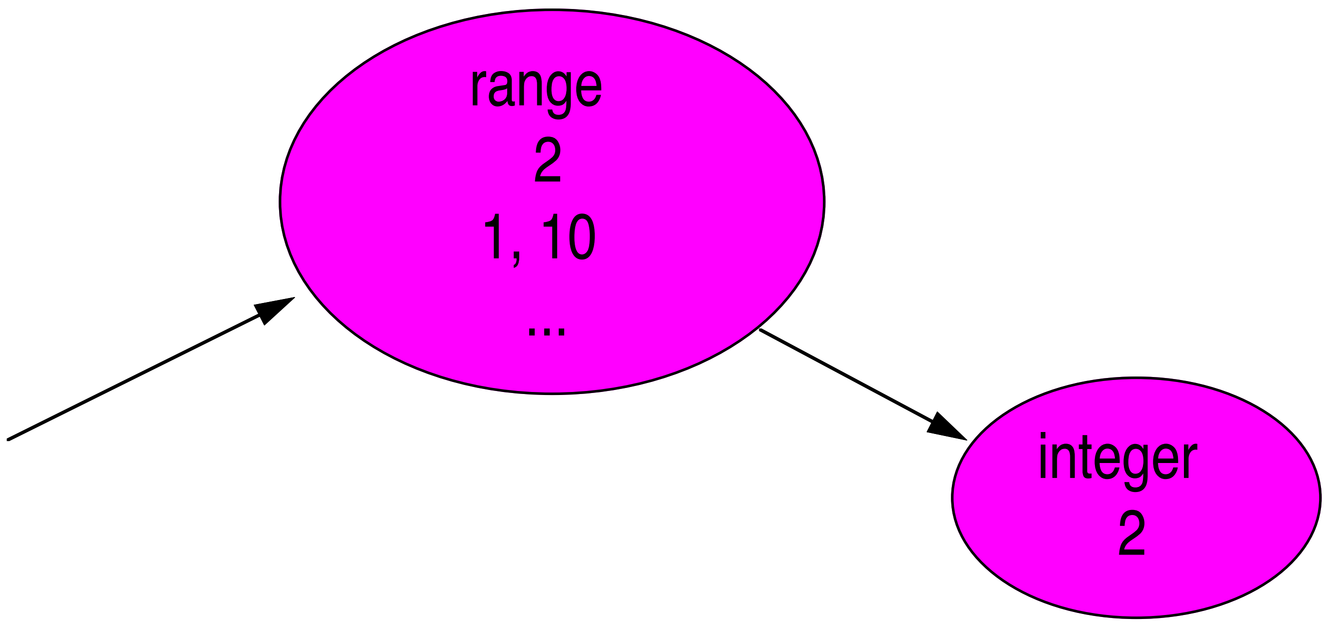
Recursive Types

[integer, [integer, Boolean]]



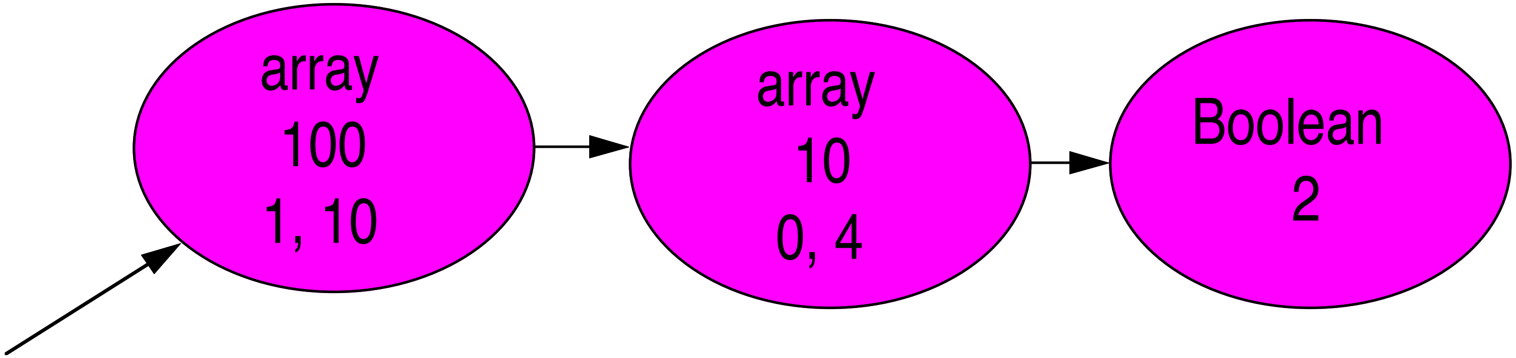
Range Types

integer range[1..10]



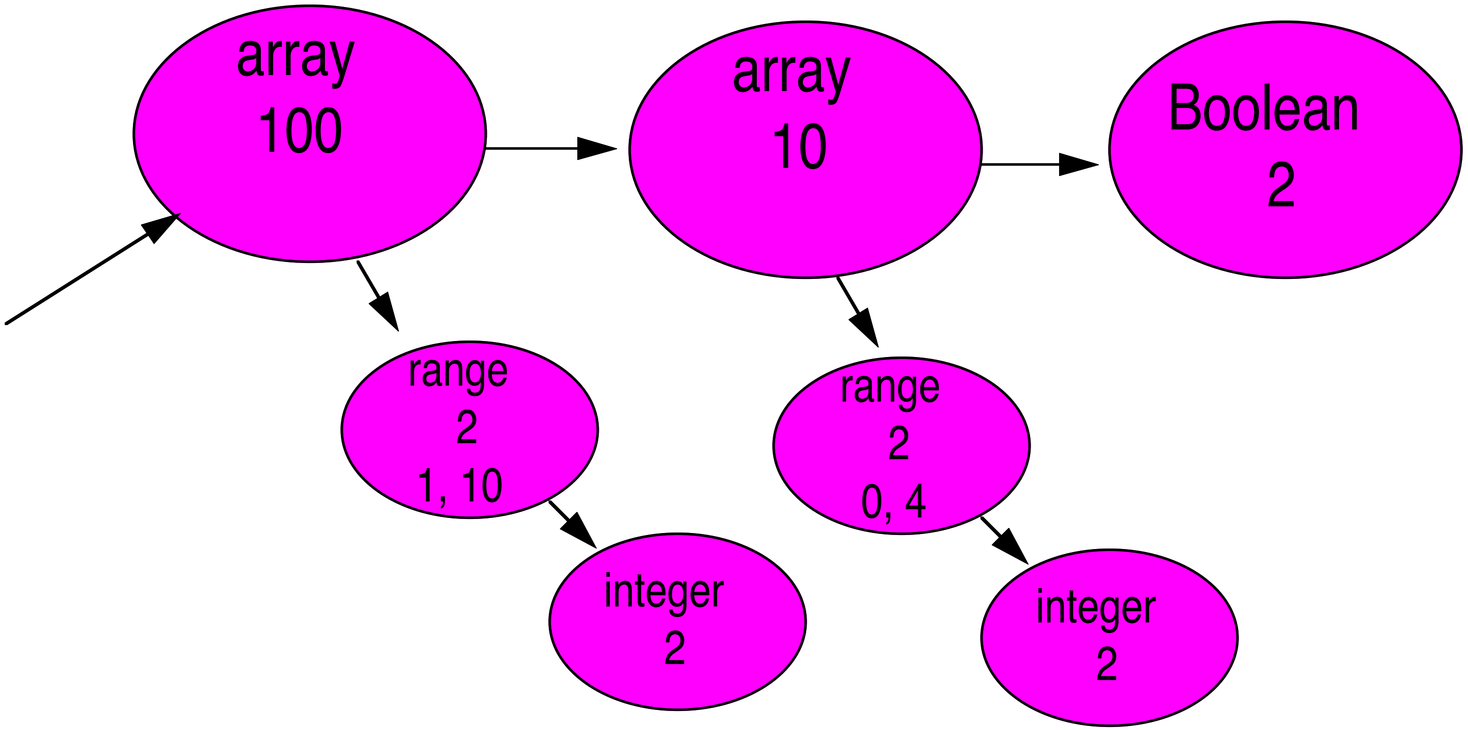
Array Types

Boolean array[1..10][0..4]



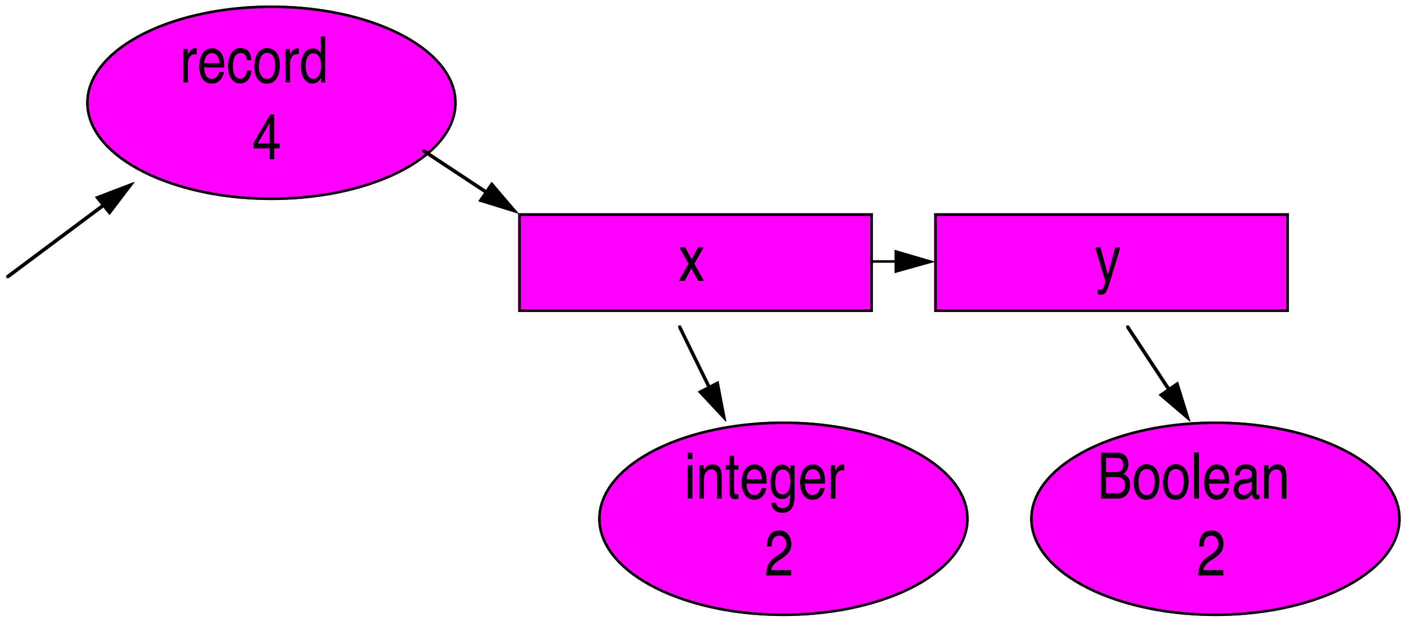
Array Types (alternate)

Boolean array [range1] [range2]



Record Types

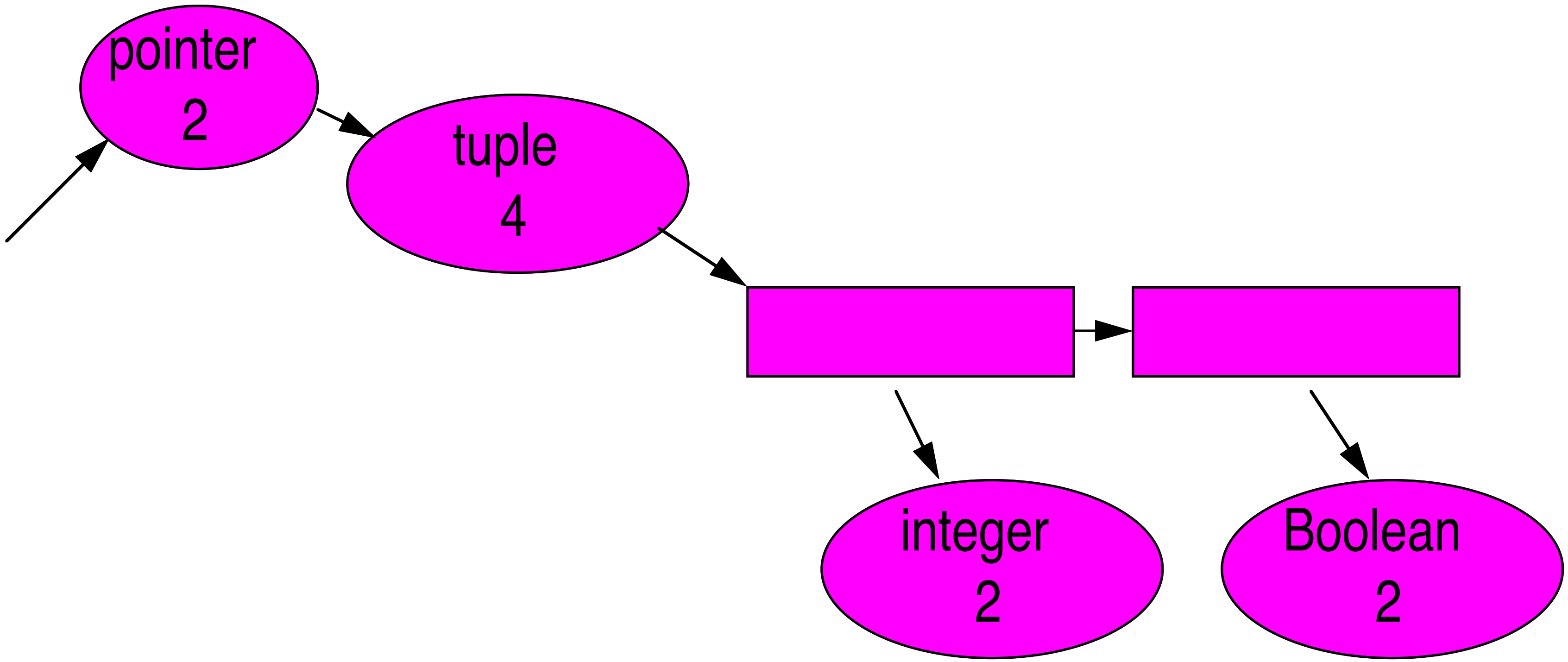
record [integer x, boolean y]



Note similarity to tuple types.

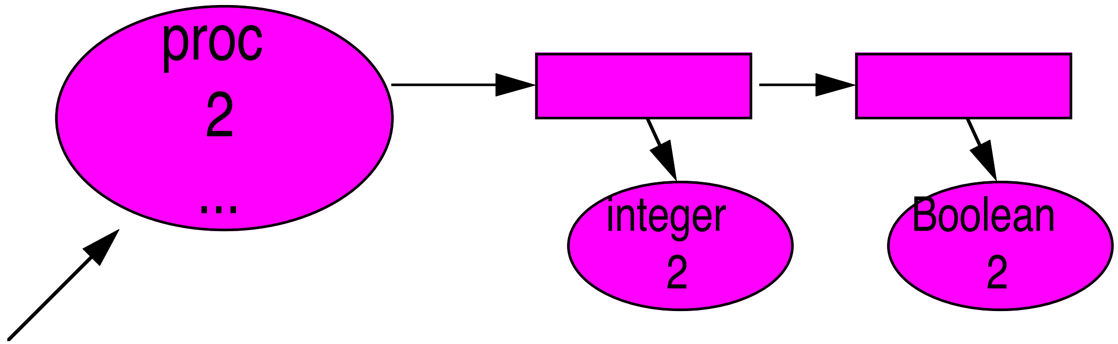
Pointer Types

pointer [integer, Boolean]



Procedure Types

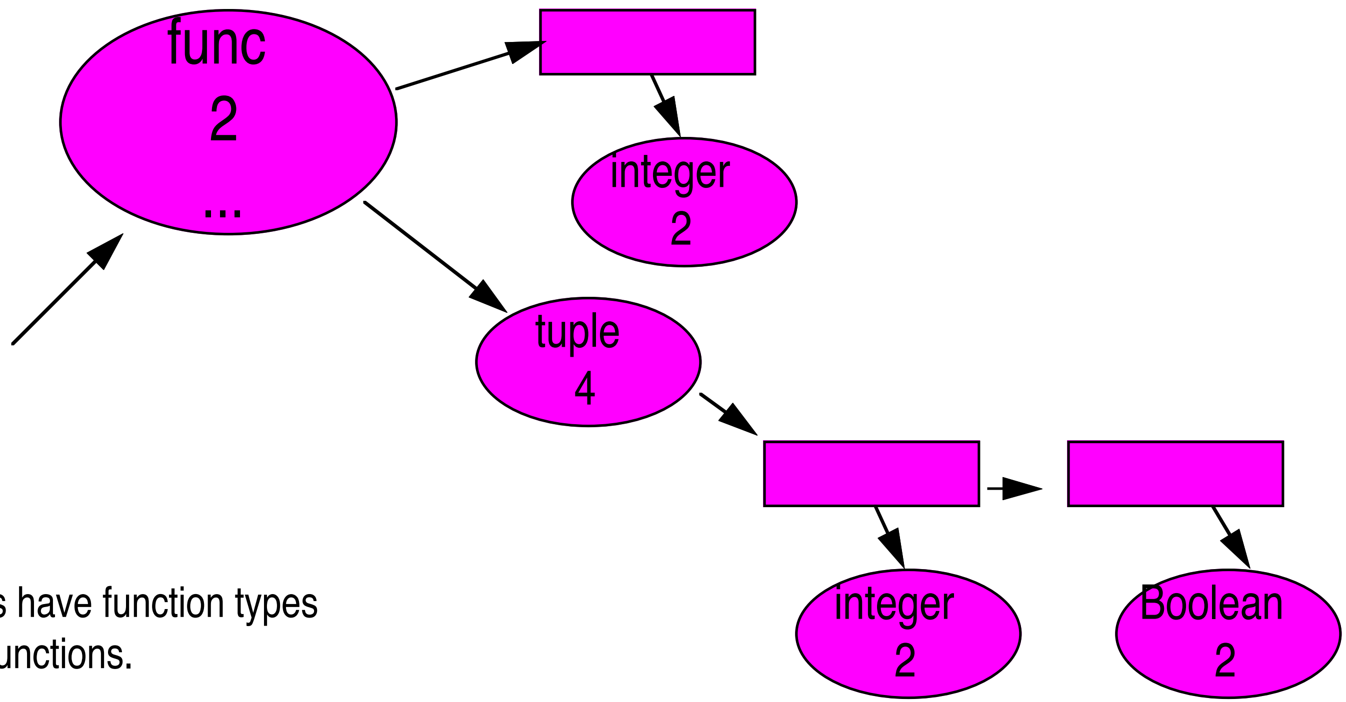
proc (integer, Boolean)



Note: Not all languages have procedure types
even when they have procedures.

Function Types

func (integer returns [integer, Boolean])

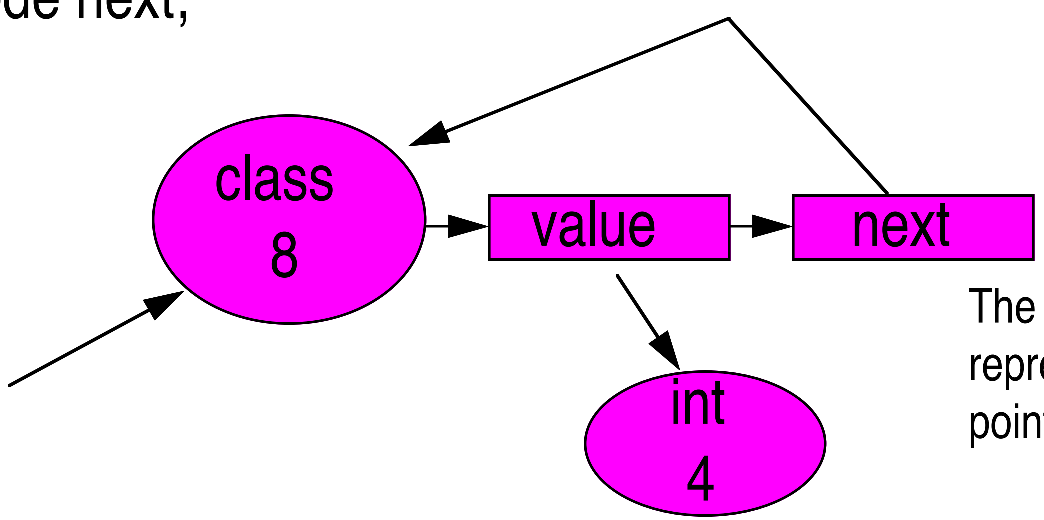


Note: Not all languages have function types
even when they have functions.

Self Recursive Types

Some languages (Java, Modula-3) permit a type to reference itself:

```
class node
{        int value;
         node next;
}
```



The internal representation is a pointer (4 bytes)

Recursive Types Again

```
[       record [integer array[0..4] x, Boolean y] ,
        integer range [1..10] ,
        pointer [integer, integer] ,
        func(integer, Boolean returns integer array[1..5])
]
```

Left as an exercise. :-)