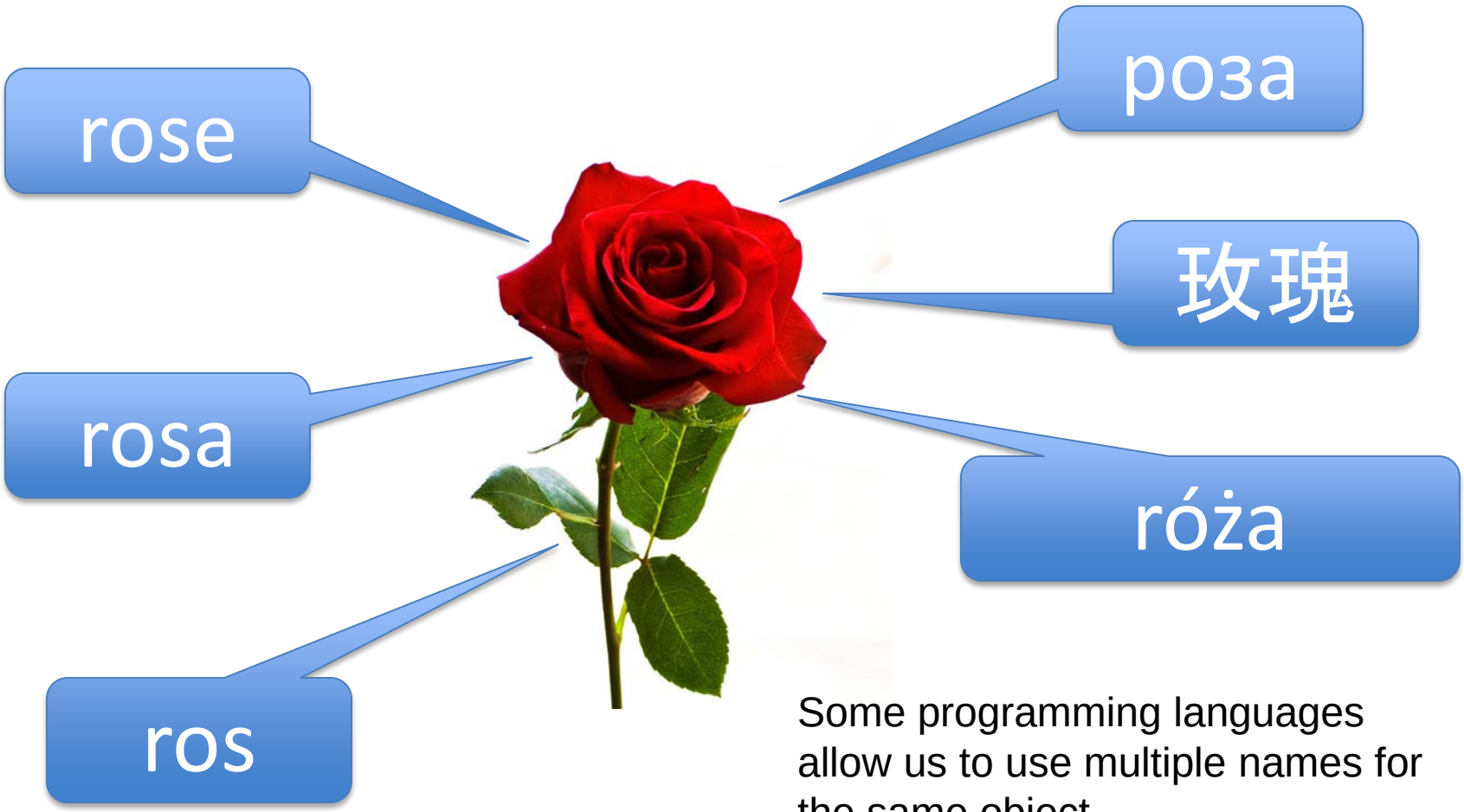
Why Symbol Tables?

What's in a name? That which we call a **rose**, *by any other name would smell as sweet…*

Romeo and Juliet by Henri-Pierre Picou

Why Symbol Tables?



Some programming languages allow us to use multiple names for the same object.
(For instance: references in C++).

Why Symbol Tables?

rose

rose

rose

rose?

The same word could mean different objects in different contexts.
(For example: a local variable and a global variable).

Symbol Table

- It records information about *symbol names* in a program.
- Don't confuse *symbol* and *identifier*:
  - A **symbol** (or **name**) is the object (variable, function, procedure, program, etc).
  - An **identifier** is a way to reference some symbol.

rose

When is the Symbol Table used?

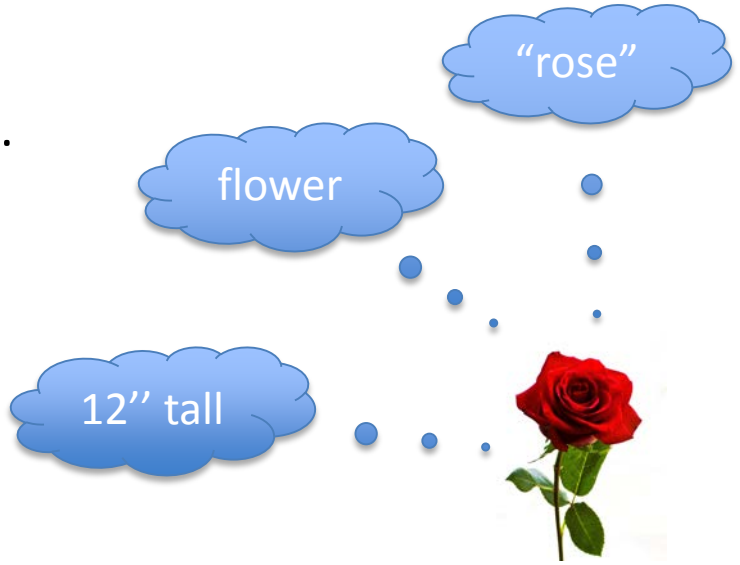
- Lexical Analysis
  - Lexical Analyzer scans program
  - Finds Symbols
  - Adds Symbols to symbol table
- Syntactic Analysis
  - Information about each symbol is filled in
- Used for type checking during semantic analysis

Info provided by Symbol Table

- Given an identifier which *symbol* is it?
- What information is to be associated with a *name*?
- How do we access this information?
- How do we associate this information with a name?

Symbol Attributes

- Each piece of info associated with a name is called an **attribute**.
- Attributes are language dependent:
  - Actual characters of the name (“rose”).
  - Type (variable, function, program, etc).
  - Storage allocation info (number of bytes).
  - Line number where declared.
  - Lines where referenced.
  - Scope.



Symbol Classes

- Different Classes of Symbols have different Attributes.
- Variable, Type, Constant, Parameter, Record field.
  - Type is one of attributes (*int, float, char*).
- Procedure or function.
  - Number of Parameters, Parameters, Result Type.
- Array
  - Number of Dimensions, Array bounds.
- File
  - Record Size, Record Type.

Other Attributes

- A scope of a variable can be represented by
  - A number (scope is just one of attributes).
  - A different symbol table is constructed for different scope.
- Object Oriented languages have classes like
  - Method names, class names, object names.
  - Scoping is VERY important. (Inheritance).
- Functional Languages Lisp
  - Binding Issues.

Symbol Table Operations

- Two operations required:
  - **Insert**: adds a symbol to the table.
  - **Lookup**: finds a symbol in the table (and get its attributes).
- Insertion is only done once per symbol.
- Lookup is done many times per symbol.
- We need fast lookups.

Example program

```
01  PROGRAM Main
02    GLOBAL a,b
03    PROCEDURE P (PARAMETER x)
04          LOCAL a
05    BEGIN {P}
06          …a…
07          …b…
08          …x…
09    END  {P}
10  BEGIN{Main}
11    Call P(a)
12 END {Main}
```

Symbol Table: External Structure

- It refers to the way in which we handle the symbols. Could be implemented as:
  - Unordered List
  - Ordered List
  - Binary Tree
  - Hash Table

Symbol Table: Unordered List

- Fast inserts: *O*(1)
- Slow lookups: *O*(n)
- Only useful if there is a small number of symbols

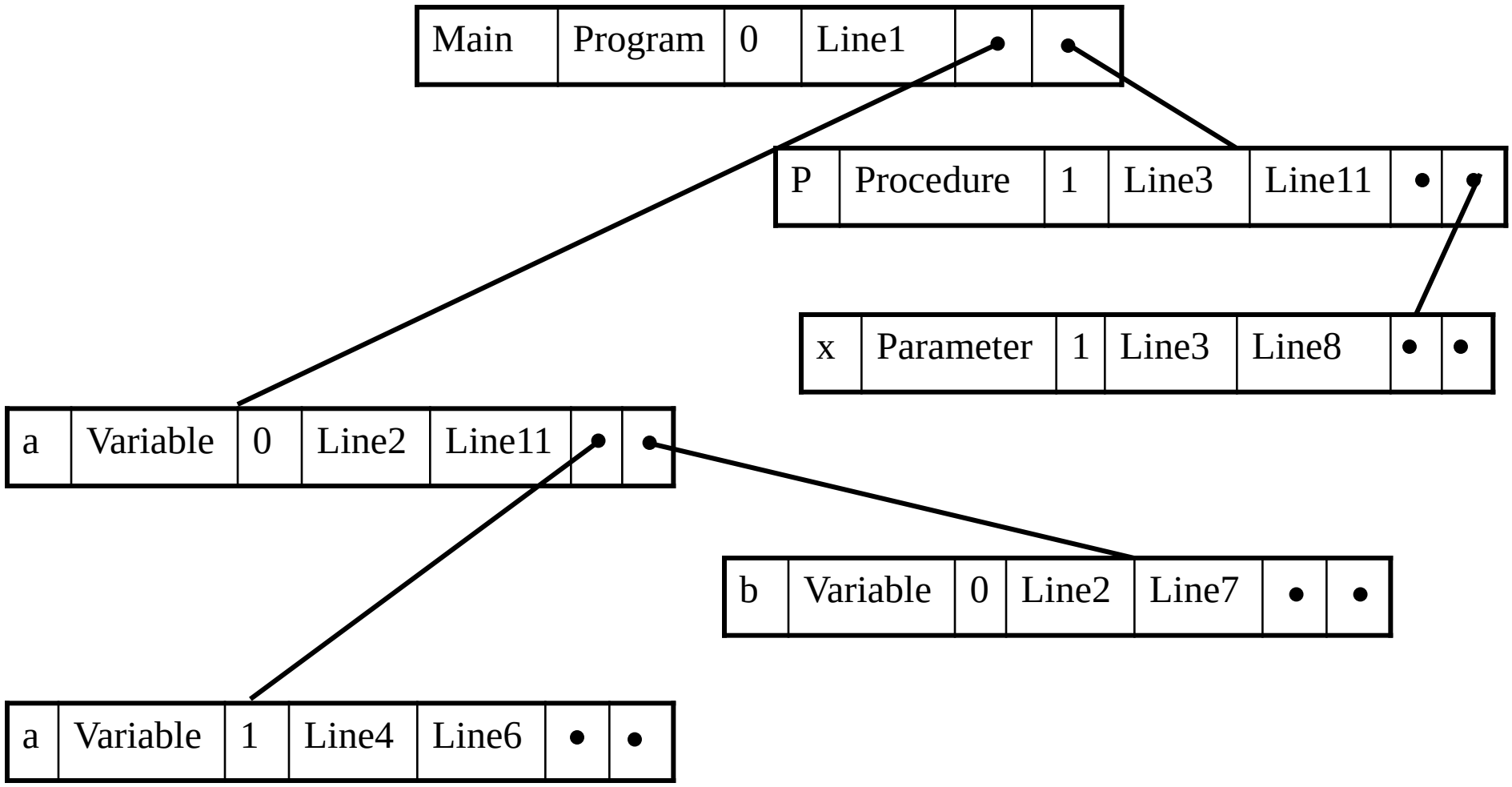
Identifier	**Class**	**Scope**
Main	Program	0
a	Variable	0
b	Variable	0
P	Procedure	0
x	Parameter	1
a	Variable	1

Symbol Table: Ordered List

- Ordered by identifier
- Ordered Array:
  - Slow inserts: *O*(n)
  - Fast lookups: *O*(log n)
- Linked List:
  - Slow inserts: *O*(n)
  - Slow lookups: *O*(n)

Identifier	Class	Scope
a	Variable	0
a	Variable	1
b	Variable	0
Main	Program	0
P	Procedure	0
x	Parameter	1

Symbol Table: Binary Tree



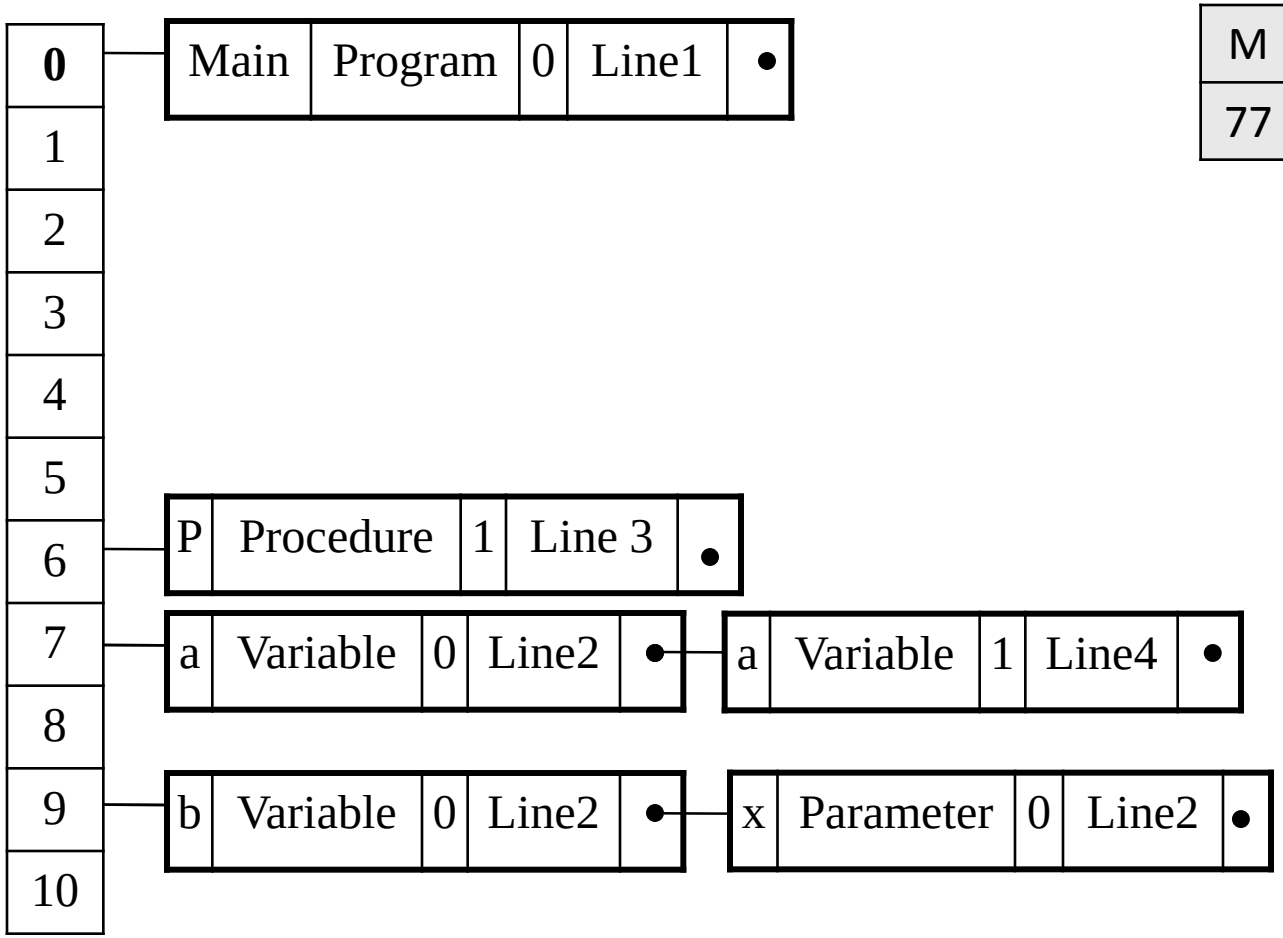
Symbol Table: Binary Tree

- Fast inserts: *O*(log n)
- Fast lookups: *O*(log n)
- Space efficient.
- Easy to print alphabetized list of names.
- Scoping is difficult, unless a different tree is used for each scope.

Symbol Table: Hash Table

- Most efficient. Used by production compilers.
- Fast insertion: *O*(1).
- Fast lookup: *O*(1) best case, *O*(n) worst case (very rare).
- A good hashing function is needed.
- As an example, let's use the following hashing function:
  - H(id) = (First letter + last letter) mod 11

Symbol Table: Hash Table



M	n	a	b	P	x
77	110	97	98	80	120

```
PROGRAM Main
GLOBAL a,b
PROCEDURE P(PARAMETER x)
LOCAL a
BEGIN (P)
…a…
…b…
…x…
END (P)
BEGIN  (Main)
Call P(a)
End (Main)
```

Symbol Table: Hash Table

- Scoping is easy to implement. No need to use extra tables.
- Drawbacks?
  - It is not as space efficient as a binary tree.

Symbol Table: Internal Structure

- The internal structure is how we organize each symbol and its attributes.
- Logical view: a symbol table is a list of names, and each name has a list of attributes.
- Implementation: a symbol table might have multiple tables:
  - String table.
  - Class table.
  - Name table.

Example of Internal Structure

```
rose: Array [1…100] of Integer;
```