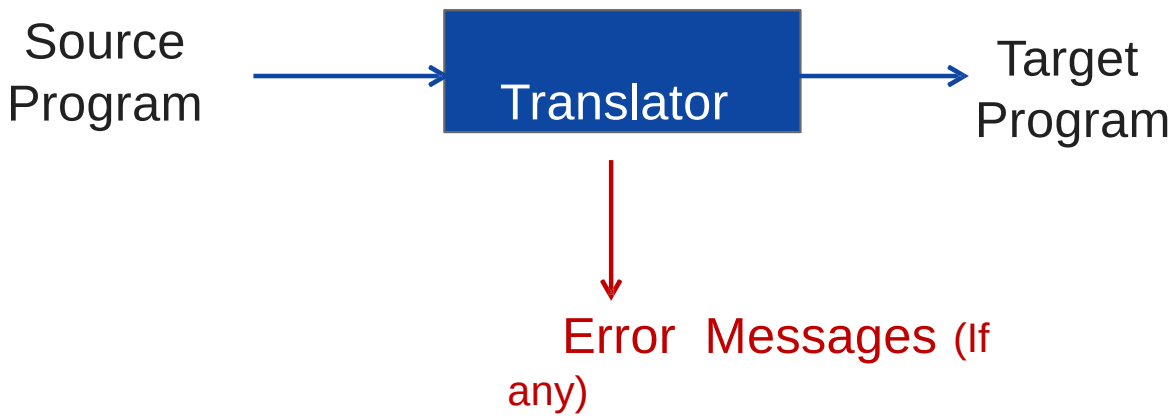
Compiler Design
Unit-1 Introduction

Introduction to translators- Assembler, Compiler, Interpreter, Difference between Compiler and Interpreter, Linker, Loader , one pass compiler, multi pass compiler, cross compiler , The components of Compiler, Stages of Compiler: Front end, Back end, Qualities of Good Compiler

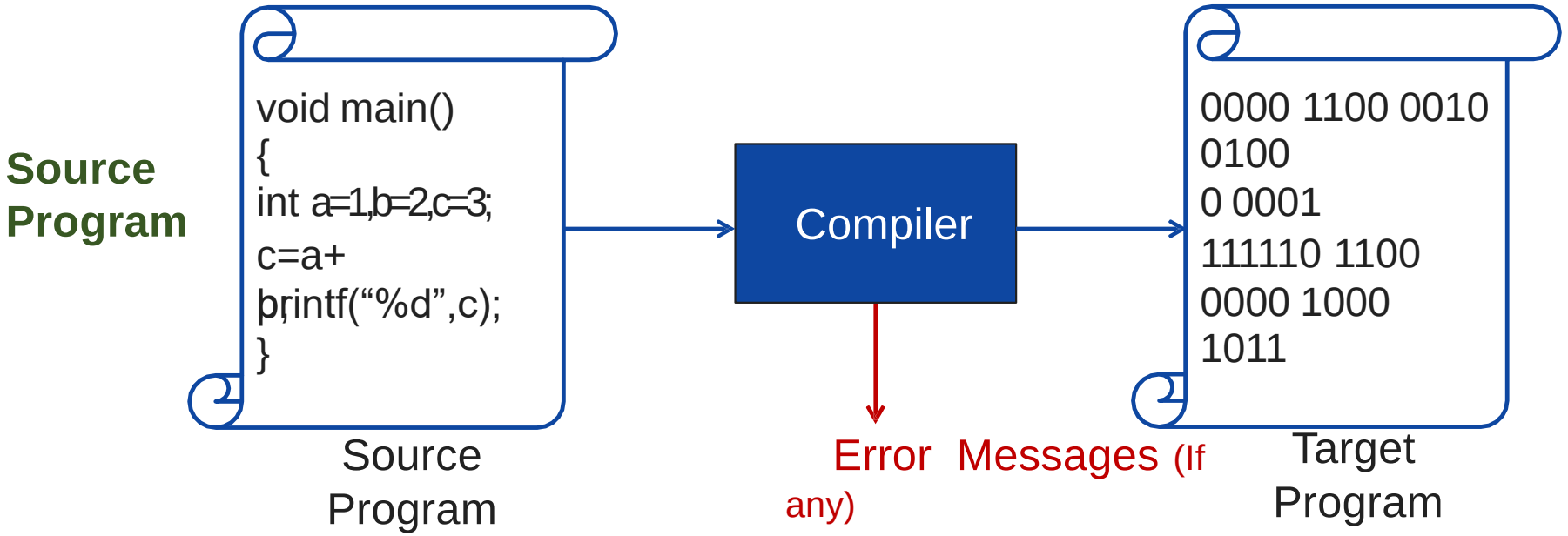
Translator

- A translator is a program that **takes one form of program as input** and **converts it into another form.**
- Types of translators are:
  1. Compiler
  2. Interpreter
  3. Assembler



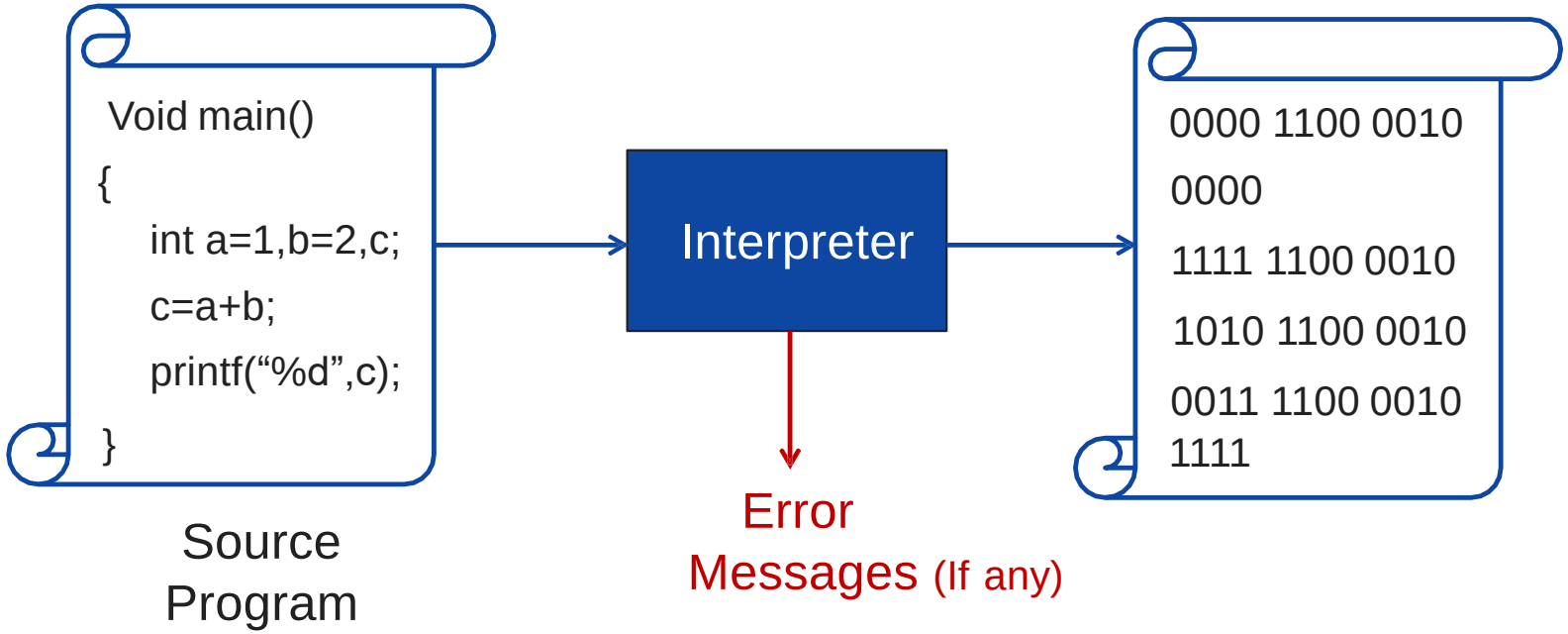
Compiler

- A compiler is a program that reads a program written in source language and translates it into an equivalent program in target language



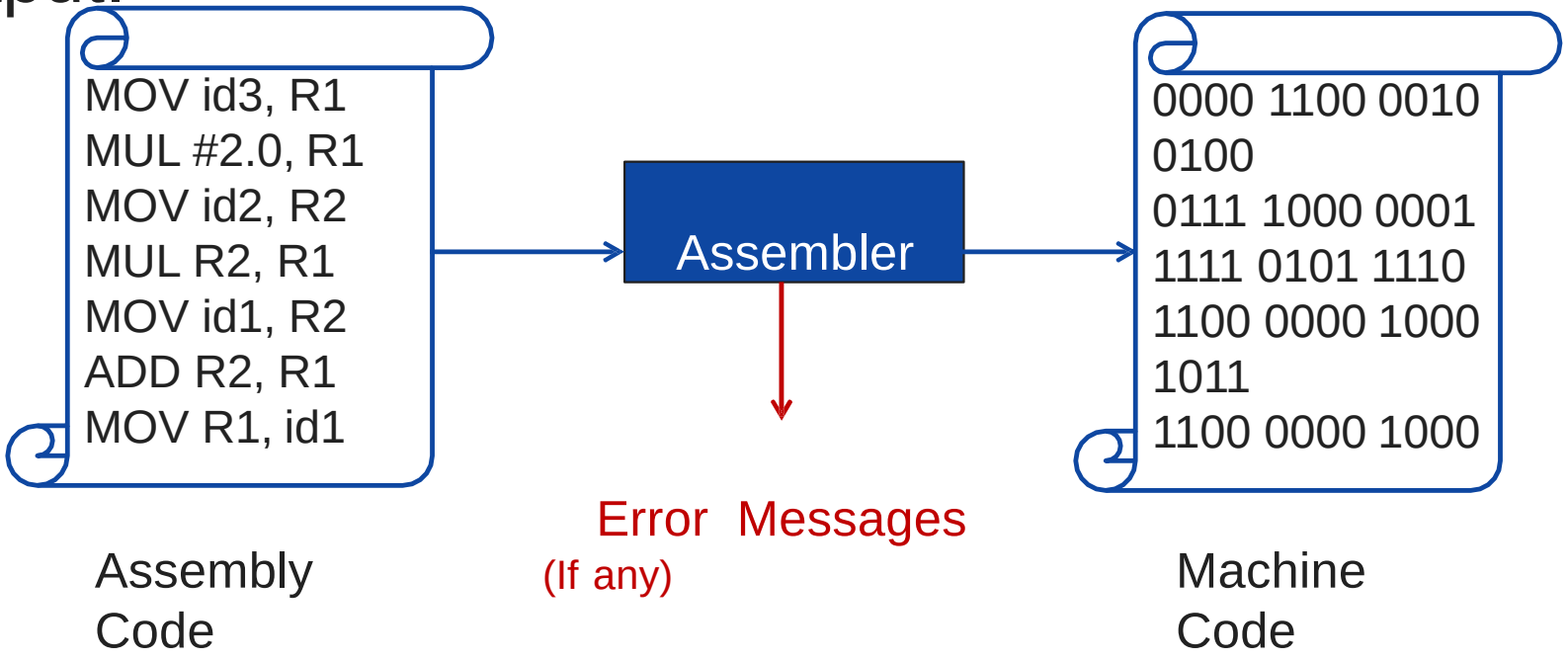
Interpreter

- Interpreter is also program that reads a program written in source language and translates it into an equivalent program in target language line by line.



Assembler

- Assembler is a translator which takes the assembly code as an input and generates the machine code as an output.

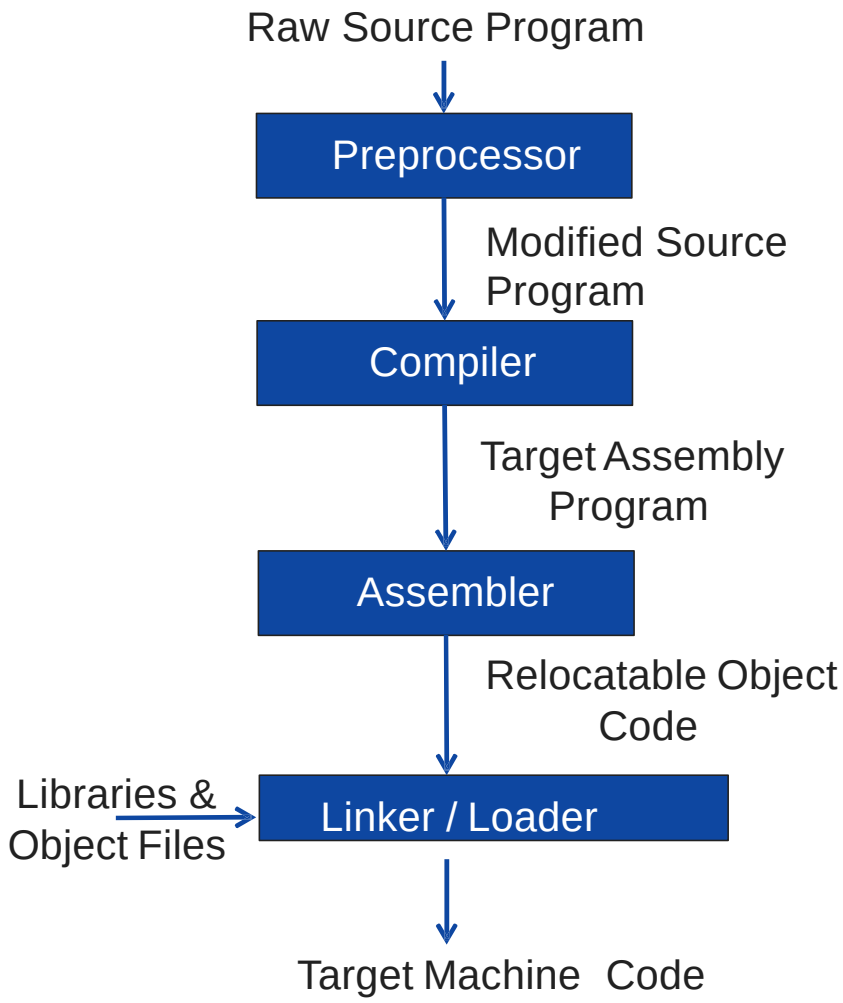


Difference between compiler & interpreter

Compiler	Interpreter
Scans the entire program and translates it as a whole into machine code.	It translates program's one statement at a time.
It generates intermediate code.	It does not generate intermediate code.
An error is displayed after entire program is checked.	An error is displayed for every instruction interpreted if any.
Memory requirement is more.	Memory requirement is less.
Example: C compiler	Example: Basic, Python, Ruby

Language Processing System

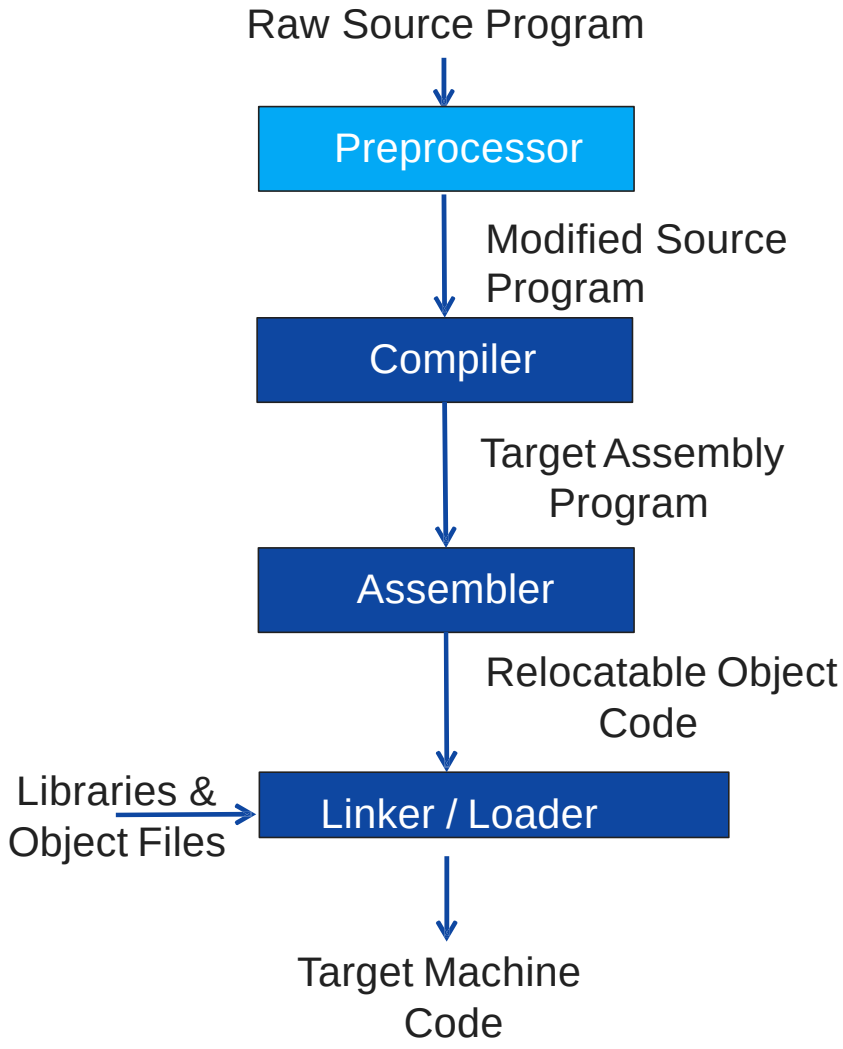
- In addition to compiler, many other system programs are required to generate absolute machine code.
- These system programs are:
  - ➥ Preprocessor
  - ➥ Assembler
  - ➥ Linker
  - ➥ Loader



Language Processing System

- **Some of the task performed by preprocessor:**

1. **Macro processing**: Allows user to define macros.
   Ex: #define PI 3.14159265358979323846
2. **File inclusion**: A preprocessor may include the header file into the program. Ex: #include<stdio.h>
3. **Rational preprocessor**: It provides built in macro for construct like while statement or if statement.
4. **Language extensions**: Add capabilities to the language by using built-in macros.
   - Ex: the language equal is a database query language embedded in C. Statement beginning with ## are taken by preprocessor to be database access, statement unrelated to C and translated into procedure call on routines that perform the database access.



Language Processing System

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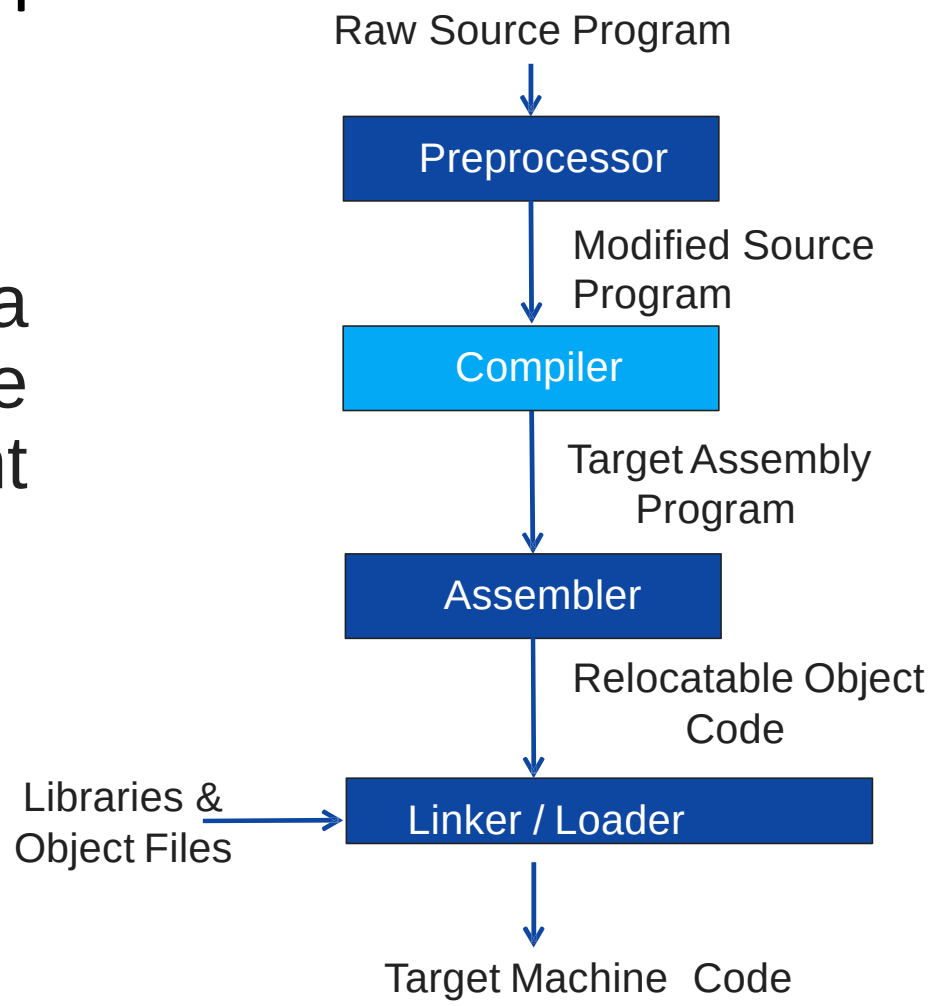
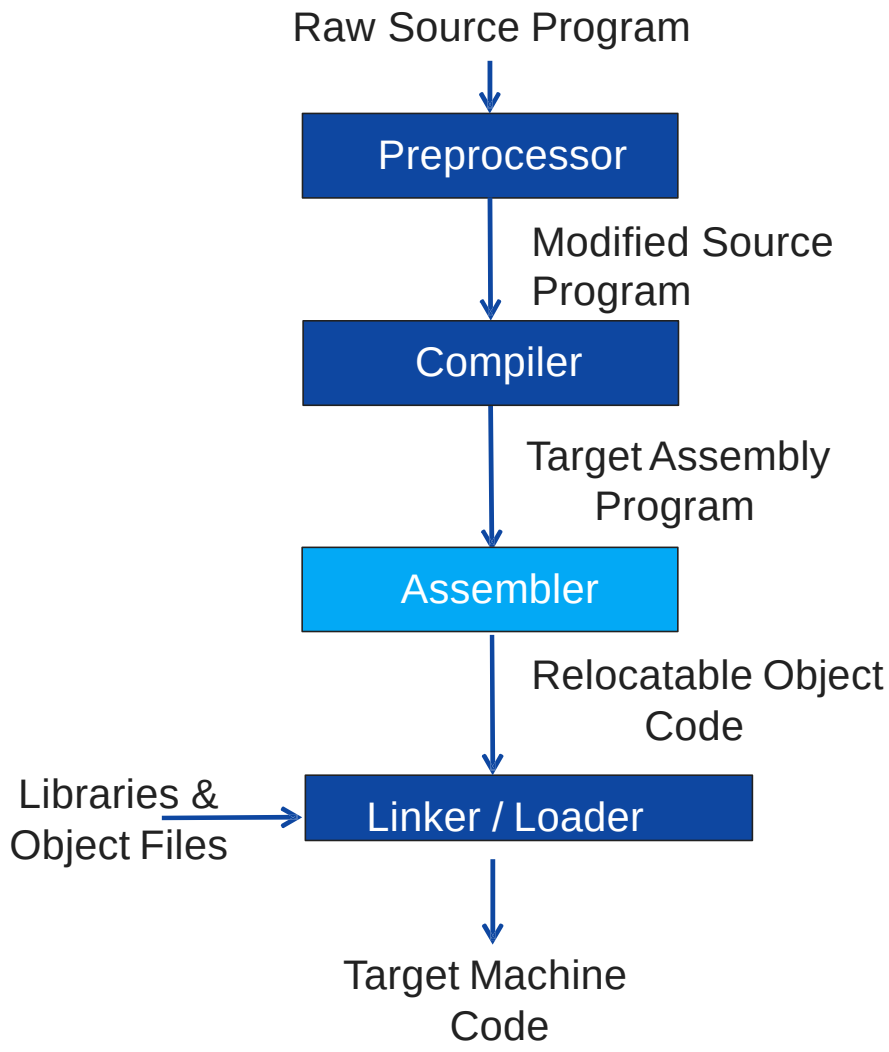


Language Processing System

Assembler

- Assembler is a translator which takes the assembly program (mnemonic) as an input and generates the machine code as an output.



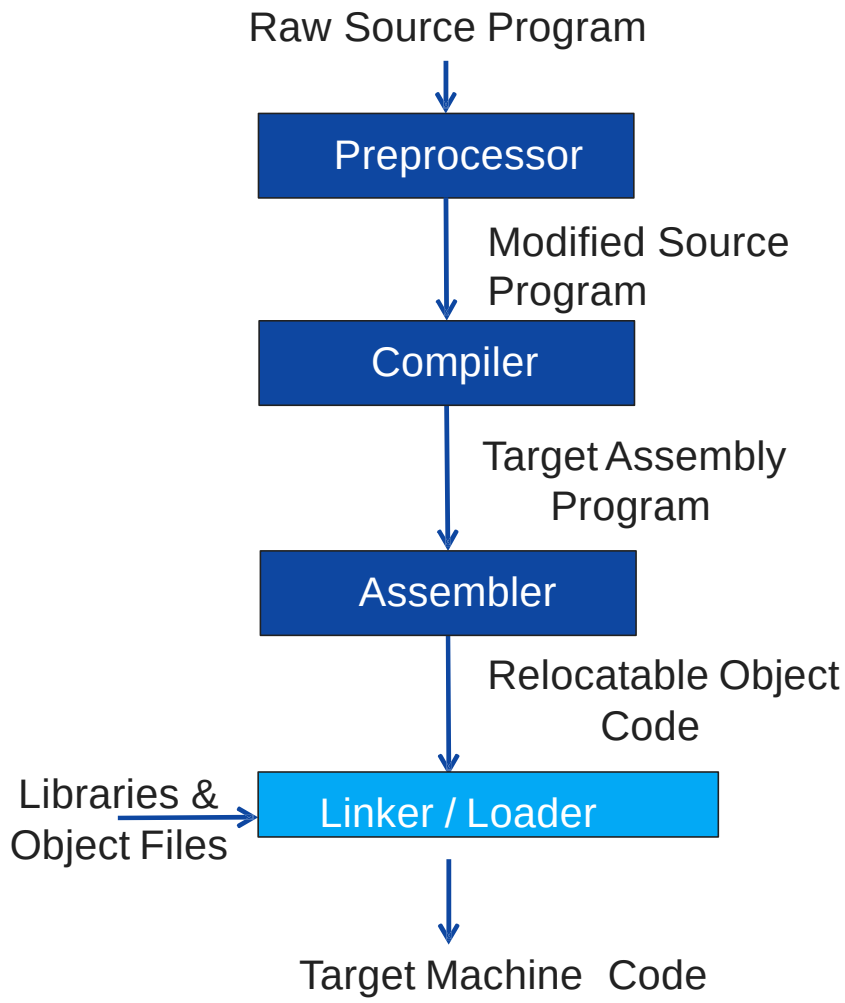
Language Processing System

Linker

- Linker makes a single program from a several files of relocatable machine code.
- These files may have been the result of several different compilation, and one or more library files.

Loader

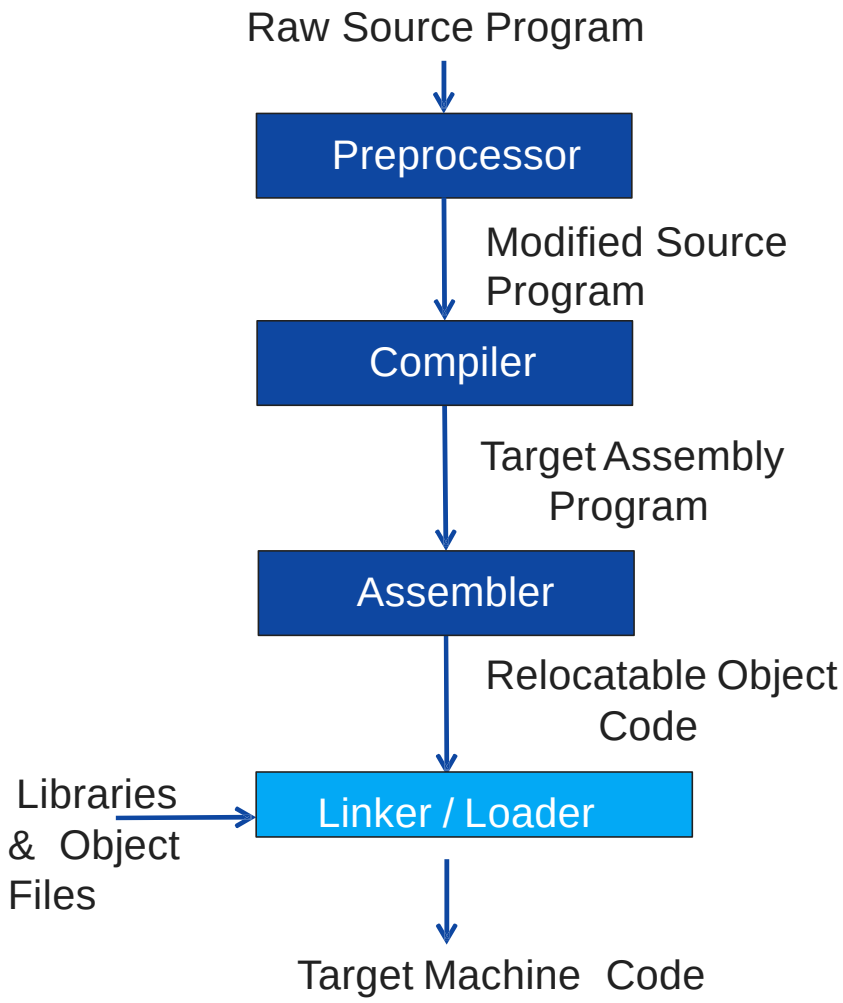
- The process of loading consists of:
  - Taking relocatable machine code
  - Altering the relocatable address
    - Placing the altered instructions and data in memory at the proper location.



Language Processing System

- The linker and loader are essential components in the compilation process.
- The linker is responsible for combining multiple object files generated by the compiler into a single executable file or library. It resolves symbols and references between different object files, ensuring that functions and variables are correctly linked together.
- For example, suppose you have two C source files, main.c and functions.c, which need to be compiled separately:

```
gcc -c main.c
gcc -c functions.c
```

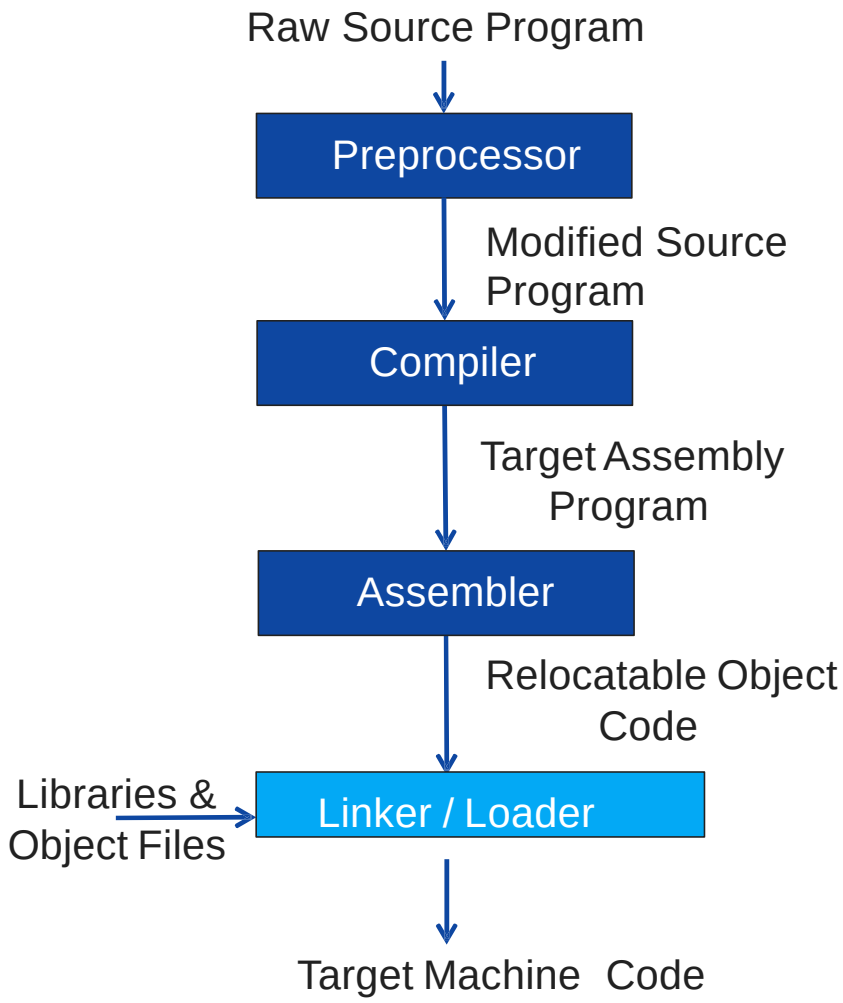


Language Processing System

- This will generate two object files: main.o and functions.o. The linker comes into play when you want to create an executable from these object files:

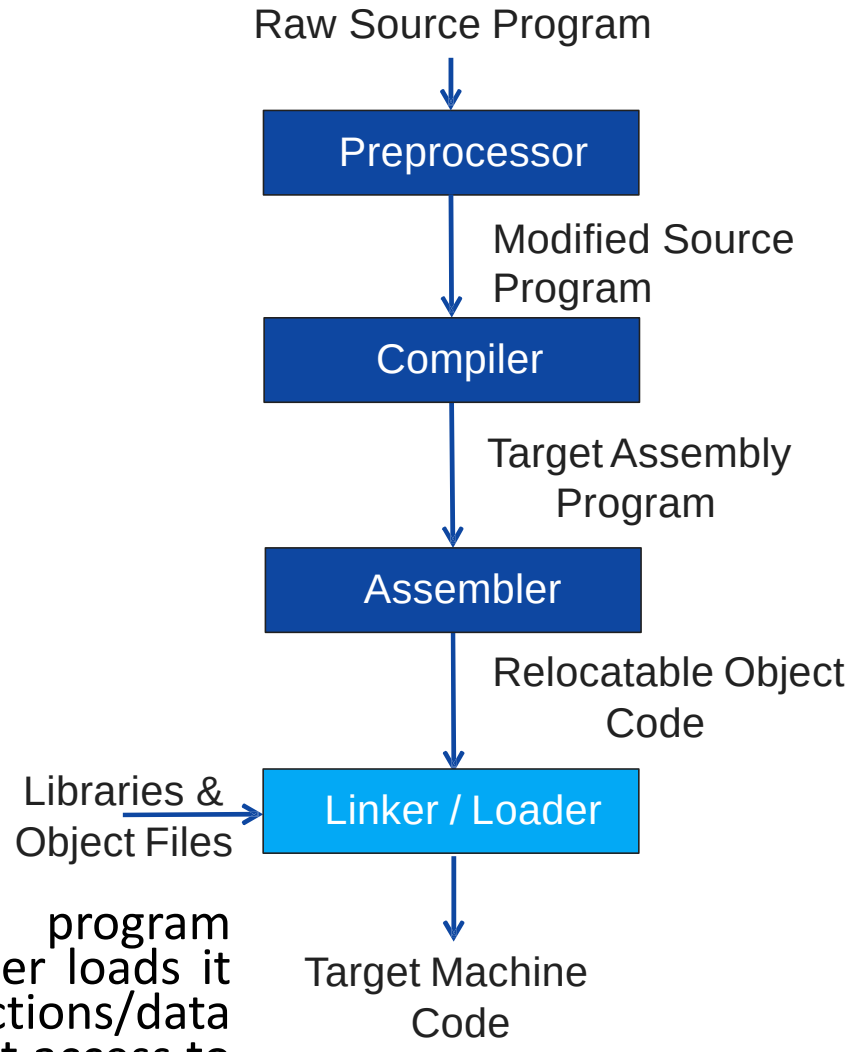
```
gcc main.o functions.o -o program
```

- Here, the linker (ld) combines both object files (main.o and functions.o) to create an executable called program. It resolves any unresolved symbols or references between them.



Language Processing System

- Loader: After linking, the resulting executable file needs to be loaded into memory for execution. This is where the loader comes in. The loader is responsible for allocating memory space for the program, resolving dynamic dependencies (if any), and preparing it for execution.
- Continuing with our previous example, once we have our executable file program, we can run it:




```
./program
```

- At this point, before executing the program instructions, the operating system's loader loads it into memory by mapping its sections/data structures appropriately. This allows direct access to resources such as code segments and data segments during runtime.

Pass structure

- One complete scan of a source program is called pass.
- Pass includes **reading an input file** and **writing to the output** file.
- In a single pass compiler analysis of source statement is immediately followed by synthesis of equivalent target statement.
- While in a two pass compiler intermediate code is generated between analysis and synthesis phase.
- It is difficult to compile the source program into single pass due to: **forward reference**

Pass structure

- **Forward reference:** A forward reference of a program entity is a **reference to the entity which precedes its definition** in the program.
- This problem can be solved by postponing the generation of target code until more information concerning the entity becomes available.
- It leads to multi pass model of compilation.

```
int x = y + 5;
int y = 10;
```

Pass structure

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Pass

- Perform analysis of the source program and note relevant information.

Pass II:

- In Pass II: Generate target code using information noted in pass I.

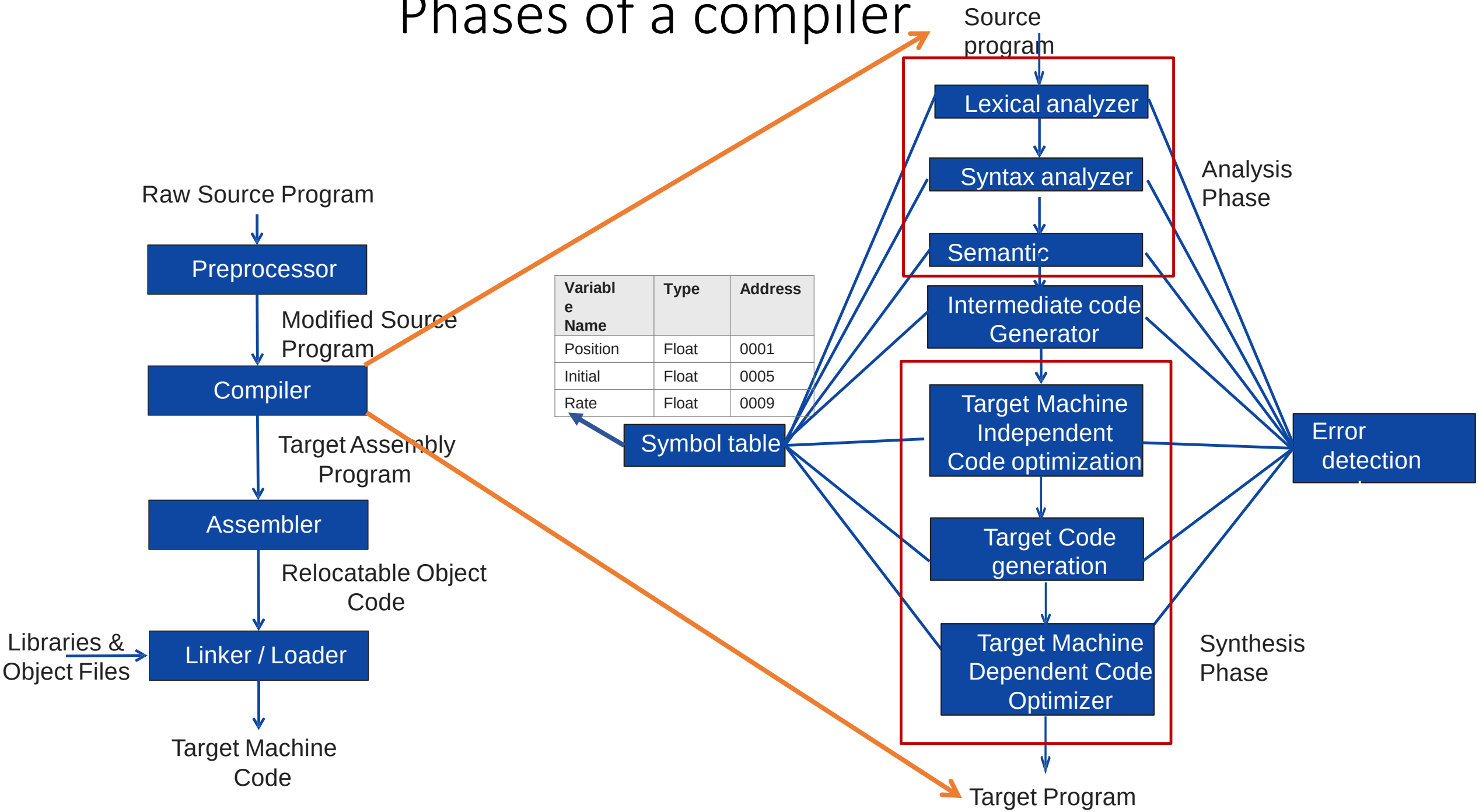
Pass structure

- Effect of reducing the number of passes:
  - It is desirable to have a few passes, because **it takes time to read and write** intermediate file.
  - If we group **several phases into one pass** then **memory requirement** may be **large**.

Types of compiler

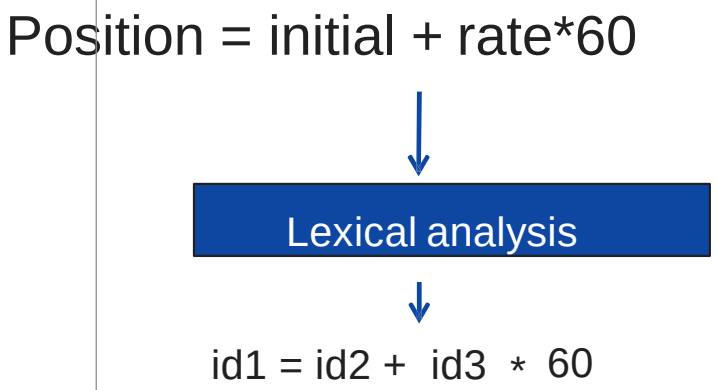
1. One pass compiler
   - It is a type of compiler that compiles whole process in one-pass.
2. Two pass compiler
   - It is a type of compiler that compiles whole process in two-pass.
   - It generates intermediate code.
3. Incremental compiler
   - The compiler which compiles only the changed line from the source code and update the object code.
4. Native code compiler
   - The compiler used to compile a source code for a same type of platform only.
5. Cross compiler
   - The compiler used to compile a source code for a different kinds platform.

Phases of a compiler

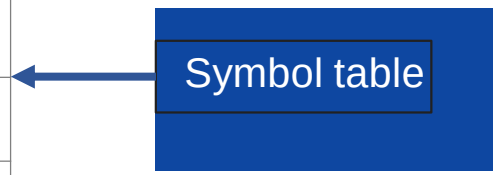


Lexical analysis

- Lexical Analysis is also called **linear analysis** or **scanning**.
- Lexical Analyzer divides the given source statement into the
- **tokens**.
- Ex:_Position = initial + rate * 60 would be grouped into the following tokens:
  - Position (identifier)
  - = (Assignment symbol) initial (identifier)
  - + (Plus symbol) rate (identifier)
  - * (Multiplication symbol) 60 (Number)

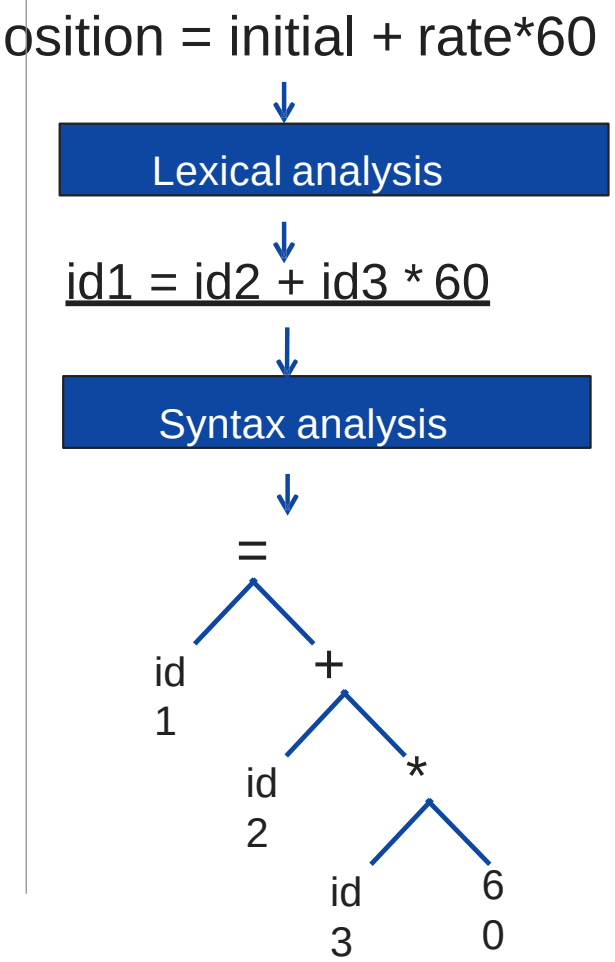


Variable Name	Type	Address
Position	Float	0001
Initial	Float	0005
Rate	Float	0009



Syntax analysis

- Syntax Analysis is also called **Parsing** or **Hierarchical Analysis**.
- The syntax analyzer checks each line of the code and spots every tiny mistake.
- If code is error free then syntax analyzer generates the tree.

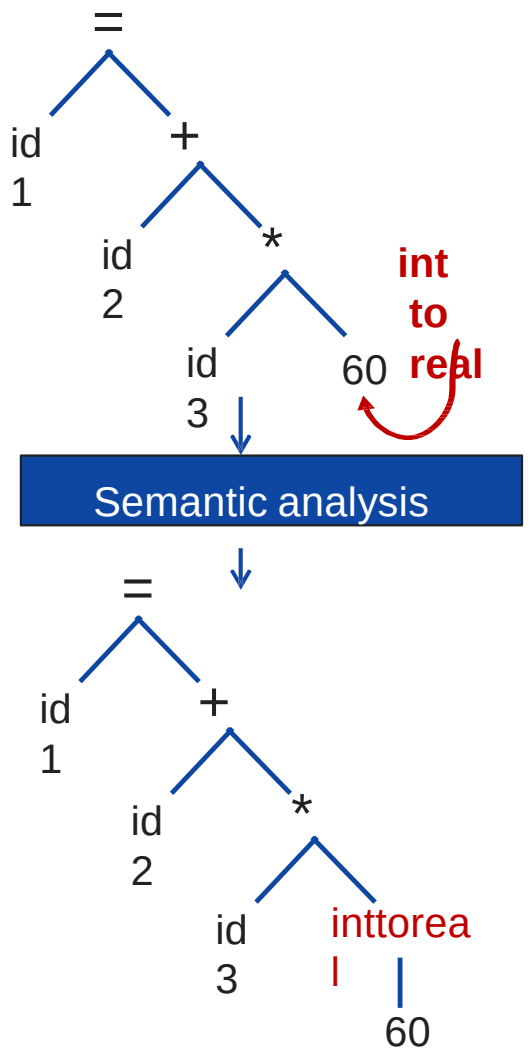


Parse tree

Semantic analysis

- Semantic analyzer determines the **meaning of a source string**.
- It performs following operations:

1. Matching of parenthesis in the expression.
2. Matching of if..else statement.
3. Performing arithmetic operation that are type compatible.
4. Checking scope of operation.



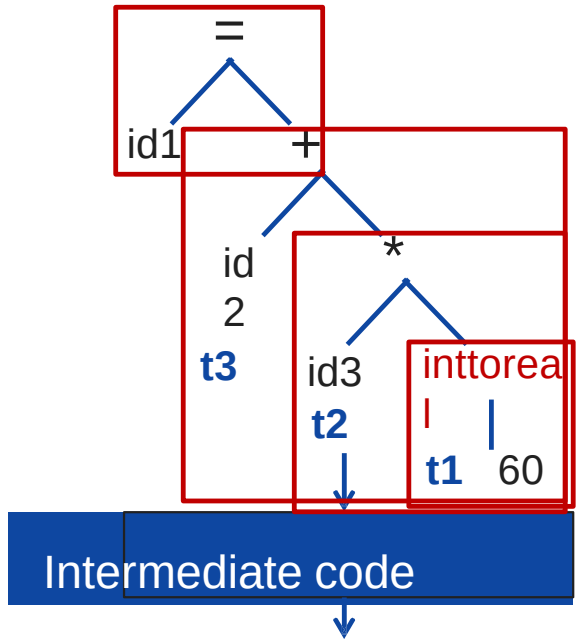
*Note: Consider id1, id2 and id3 are real

Intermediate code generator

- Two important properties of intermediate code:

1. It should be **easy to produce**.
2. **Easy to translate** into target program.

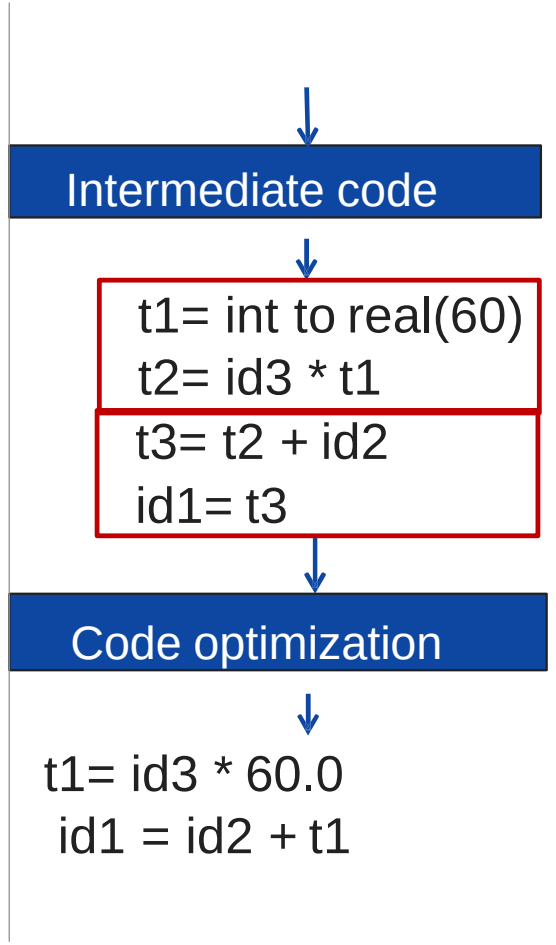
- Intermediate form can be represented using **"three address code".**
- Three address code consist of a sequence of instruction, each of which has **at most three** operands.



t1= int to real(60)
t2= id3 * t1
t3= t2 + id2
id1= t3

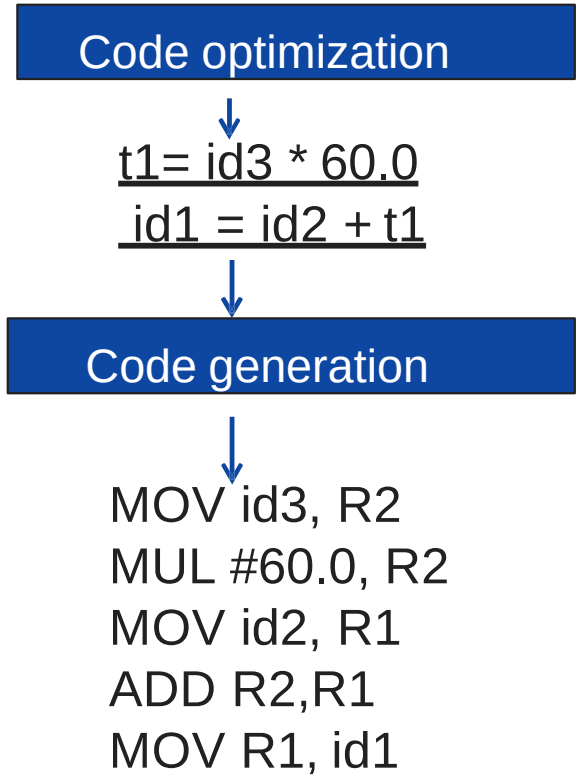
Code optimization

- It **improves** the intermediate code.
- This is necessary to have a **faster execution** of code or **less consumption of memory**.



Code generation

- The intermediate code instructions are **translated into sequence of machine instruction (assembly language)**.



Id3→R2
Id2→R1

Front end & back end (Grouping of phases)

Front end

- Depends primarily on source language and largely independent of the target machine.
- It includes following phases:
    1. Lexical analysis
    2. Syntax analysis
    3. Semantic analysis
    4. Intermediate code generation
    5. Creation of symbol table

Back end

- Depends on target machine and do not depends on source program.
- It includes following phases:
    1. Code optimization
    2. Code generation phase
    3. Error handling and symbol table operation

Characteristics of Good Compiler

- Correctness
- Efficiency
- Portability
- Error Diagnostics
- Optimization Capabilities
- Modularity
- Scalability
- Support for Language Features

GATE CS 2011

1)In a compiler, keywords of a language are recognized during

(A) parsing of the program

(B) the code generation

(C) the lexical analysis of the program

(D) dataflow analysis

GATE CS 2011

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OPTION C

GATE CS 2008

- **Some code optimizations are carried out on the intermediate code because**
- (A) they enhance the portability of the compiler to other target processors
- (B) program analysis is more accurate on intermediate code than on machine code
- (C) the information from dataflow analysis cannot otherwise be used for optimization
- (D) the information from the front end cannot otherwise be used for optimization

GATE CS 2008

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- **Answer: A**

GATE CS 1997

- **A language L allows declaration of arrays whose sizes are not known during compilation. It is required to make efficient use of memory. Which of the following is true?**
- (A) A compiler using static memory allocation can be written for
- (B) A compiler cannot be written for L, an interpreter must be used
- (C) A compiler using dynamic memory allocation can be written for L
- (D) None of the above

GATE CS 1997

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- (D) None of the above
- **Answer: C**

GATE-CS-2014-(Set-3)

- **One of the purposes of using intermediate code in compilers is to**
- (A) make parsing and semantic analysis simpler.
- (B) improve error recovery and error reporting.
- (C) increase the chances of reusing the machine-independent code optimizer in other compilers.
- (D) improve the register allocation.

GATE-CS-2014-(Set-3)

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- **Answer: C**

- **In a two-pass assembler, symbol table is**
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- **How many tokens will be generated by the scanner for the following statement ?**
- **x = x ∗ (a + b) – 5;**
- (A) 12
- (B) 11
- (C) 10
- (D) 07

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- **Answer: A**

- **Symbol table can be used for:**
- A) Checking type compatibility
- B) Suppressing duplication of error message
- C) Storage allocation
- D) All of these

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- **Answer: D**

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- A)Linear list
- B) Search tree
- C) Hash table
- D) Self organization list

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GATE CSE 2009

- **Match all items in Group 1 with the correct options from those given in Group 2.**
- (A) P-4, Q-1, R-2, S-3
- (B) P-3, Q-1, R-4, S-2
- (C) P-3, Q-4, R-1, S-2
- (D) P-2, Q-1, R-4, S-3

Group 1	Group 2
P. Regular expression	1. Syntax Analysis
Q. Pushdown automata	2. Code Generation
R. Dataflow analysis	3. Lexical Analysis
S. Register allocation	4. Code Optimization

GATE CSE 2009

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- (D) P-2, Q-1, R-4, S-3
- **Answer: B**

GATE CSE 2010

- Which data structure in a compiler is used for managing information about variables and their attributes?
- (A) Abstract Syntax Tree
- (B) Symbol Table
- (C) Semantic Stack
- (D) Parse Table

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ISRO 2020

- The number of tokens in the following C code segment is
- A. 27
- B. 29
- C. 26
- D. 24

```
1.switch(inputvalue)
2.{
3.case 1 : b =c*d; break;
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ISRO 2020

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- Answer: 26

ISRO 2020

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- **The tokens in the code segment are as follows:**
- switch - Keyword
- (- Punctuation
- inputvalue - Identifier
-) - Punctuation
- { - Punctuation
- case - Keyword
- 1 - Integer Literal
- : - Punctuation
- b - Identifier
- = - Operator
- …..

GATE CSE 2020

- **Consider the following statements.**
- I. Symbol table is accessed only during lexical analysis and syntax analysis.
- II. Compilers for programming languages that support recursion necessarily need heap storage for memory allocation in the run-time environment.
- III. Errors violating the condition ‘any variable must be declared before its use’ are detected during syntax analysis.
- Which of the above statements is/are TRUE?

A. I only
B. I and III only
C. II only
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B. I and III only
C. II only
D. None of I, II and III

- **Answer: D**

GATE CSE 2020-Explanation

- Symbol table is a data structure used by compilers to store information about the variables, functions, and other entities in a program. It is accessed during both lexical analysis and syntax analysis, but may also be used by later stages of the compilation process, such as code generation.
- Compilers for programming languages that support recursion may or may not need heap storage for memory allocation in the run-time environment. The decision to use heap storage or not depends on the specific implementation of the compiler and the features of the programming language.
- Errors violating the condition 'any variable must be declared before its use' are typically detected during the semantic analysis phase of compilation, not during syntax analysis. **Syntax analysis checks the structure of the program** to ensure it follows the rules of the programming language's grammar, while semantic analysis checks the meaning of the program to ensure it is semantically correct.

Incremental-Compiler is a compiler?

- (A) which is written in a language that is different from the source language
- (B) compiles the whole source code to generate object code afresh
- (C)compiles only those portion of source code that have been modified.
- (D)that runs on one machine but produces object code for another machine

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- (A) which is written in a language that is different from the source language
- (B) compiles the whole source code to generate object code afresh
- (C)compiles only those portion of source code that have been modified.
- (D)that runs on one machine but produces object code for another machine
- **Answer: C**

Which phase of compiler generates stream of atoms?

- (A) Syntax Analysis
- (B) Lexical Analysis
- (C) Code Generation
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- A)Dynamic memory allocation
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- **Answer: A**