MIT-WPU
Final Year (B.Tech)

System Software and Compiler Design

Unit I

Introduction to System Software and Assembler Design

- Need and Components of system software:
- Assembler, Compiler, Interpreter,
- Macro processor, Linker, Loader,
- debugger, text editor,
- Micro services and containers.

- **Assembler**: Elements of Assembler language programming,
  - Machine dependent and machine independent assembler features,
  - Design of 2 pass Assembler.

Text Books & Reference Books

Text Books:

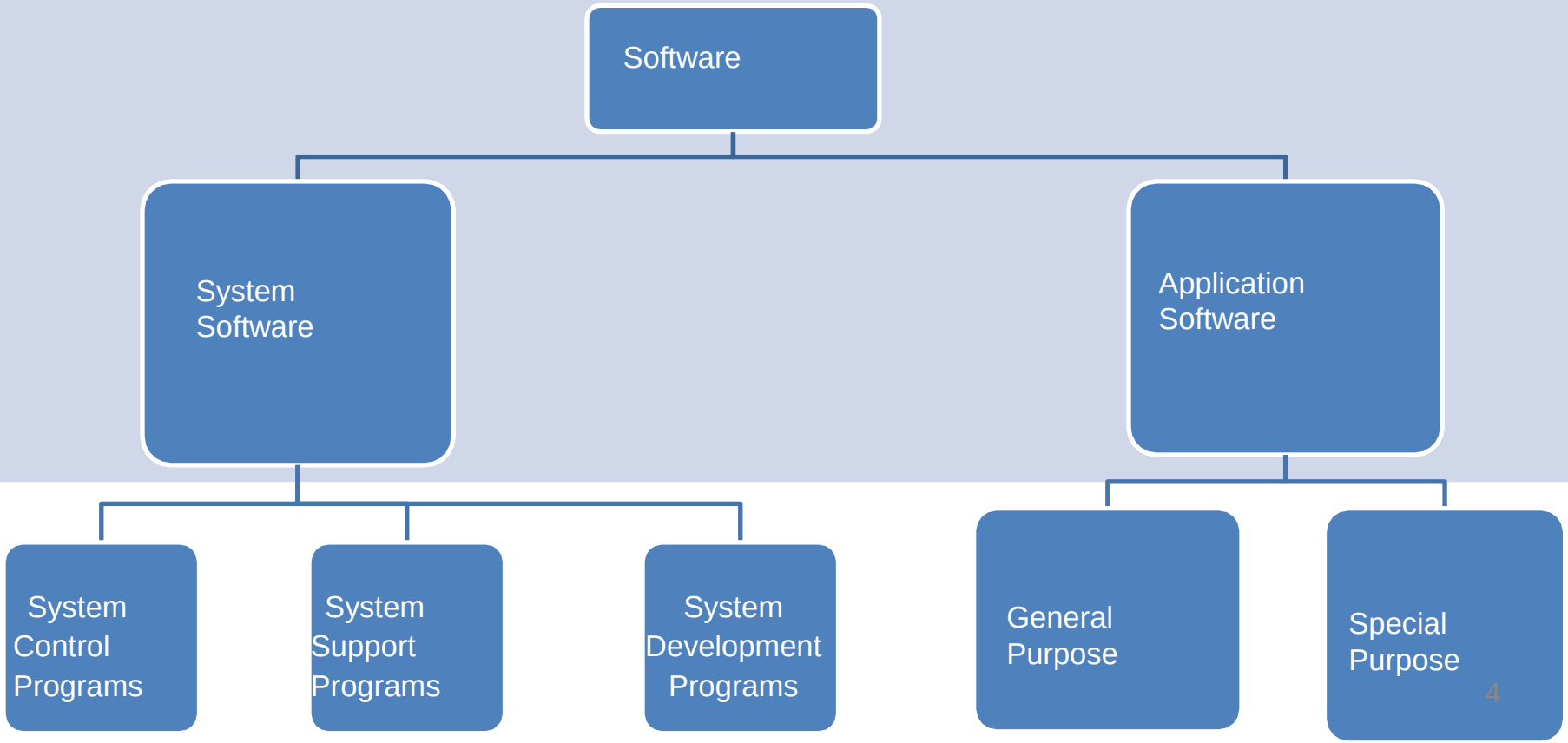
1. Dhamdhere D., "Systems Programming and Operating Systems", McGraw Hill, ISBN 0 - 07 -463579 – 4.
2. A V Aho, R Sethi, J D Ullman, \Compilers: Principles, Techniques, and Tools", Pearson Edition, ISBN 81-7758-590-8.
3. John Donovan, “System Programming”, McGraw Hill, ISBN 978-0--07-460482-3.

Reference Books:

1. John. R. Levine, Tony Mason and Doug Brown, “Lex and Yacc”, O'Reilly, 1998, ISBN: 1- 56592-000-7.
2. Leland L. Beck, “System Software An Introduction to Systems Programming” 3rd Edition, Person Education, ISBN 81-7808-036-2.
3. Adam Hoover, “System Programming with C and Unix”, Pearson,2010

Introduction to System Software

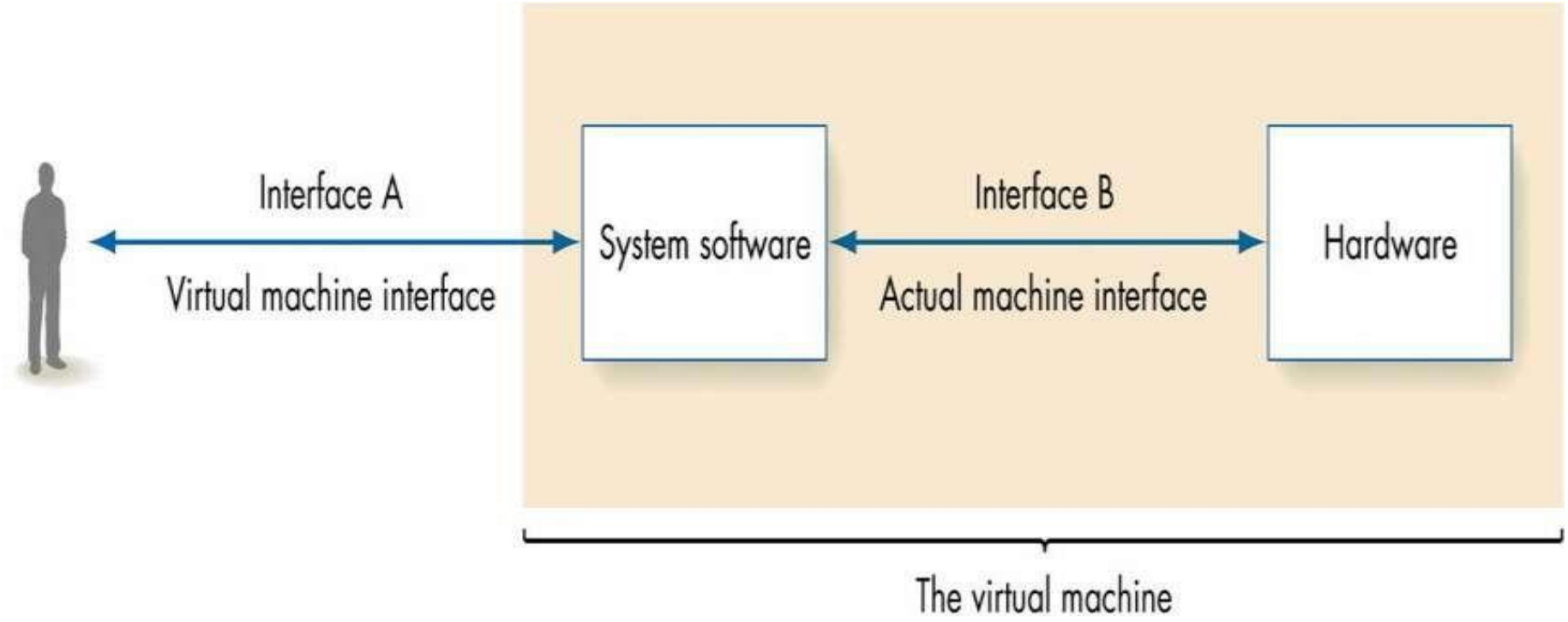
Software is a set of computer programs which are designed and developed to perform specific task desired by the user or by the computer itself.



System Software

- Collection of programs
  - Designed to
    - Operate
    - Control
    - Extend the processing capabilities of the computer itself.
- Prepared by computer manufacturers.
  - Perform functions
    - File editing,
    - Storage management,
    - Resource accounting,
    - I/O management, etc.

Role of System Software



Types of System Software

1. **System Control Programs :**
   - They control the execution of programs
   - Manage the storage and processing resources of the computer
   - Perform other management and monitoring functions.
   - e.g., OS

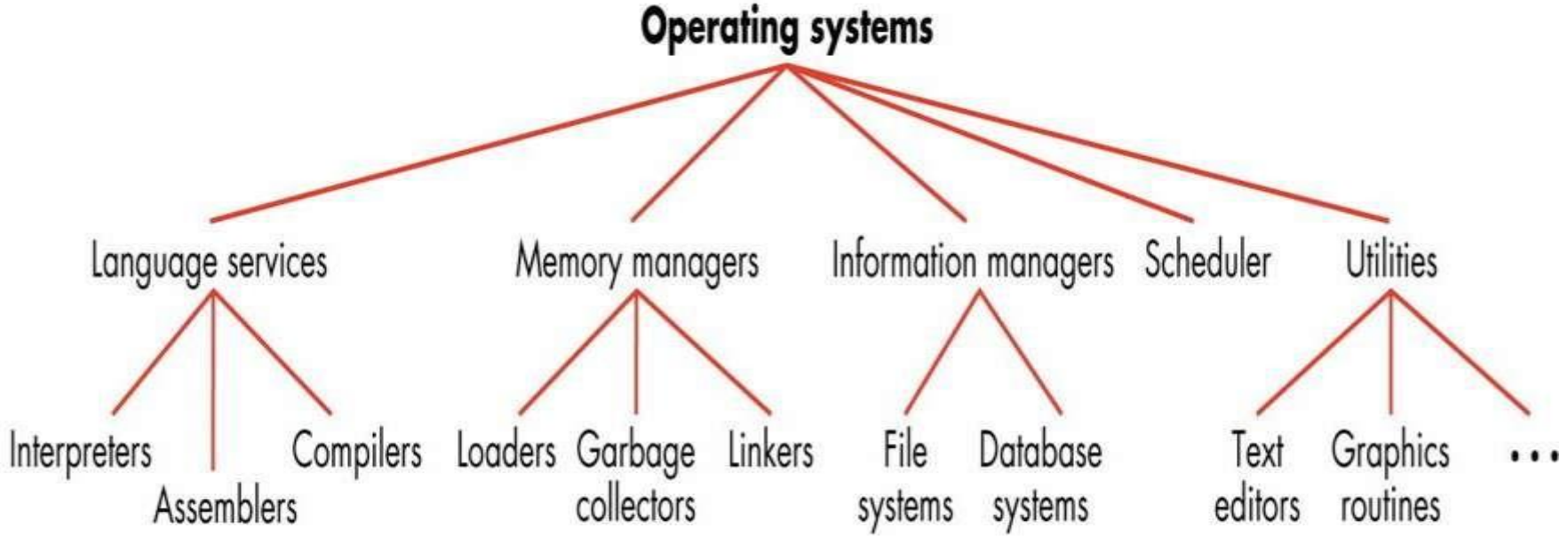
1. **System Support Programs :**
   - Provide routine service functions to other computer Programs and computer users.
   - e.g.Utility Programs

1. **System Development Programs :**
   - Assist in the creation of publication programs.

   e.g., Language translators like interpreters,

System Control Programs-OS

- An OS is an integrated set of specialized programs that are used to manage overall resources of and operations of the computer.



System Development Programs-Language Translators

•Language translators are also called language processors.

Main functions are :

- Translate high level language to low level language.
- Check for and identity syntax errors

There are **3 types of translator programs-**

1. Assembler
2. Interpreter
3. Compiler

Assemblers

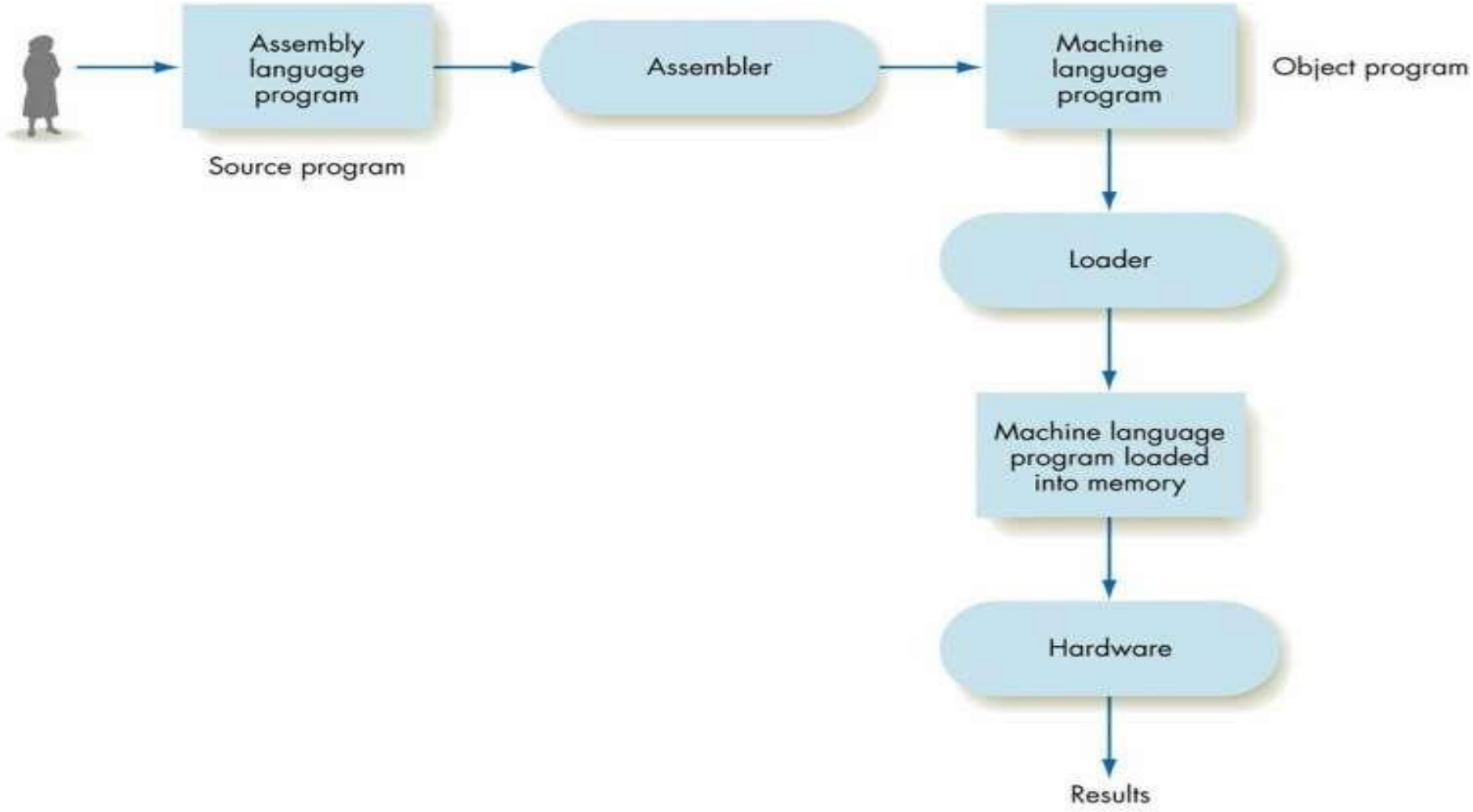
Assembly Language Program ----------
Machine Language Program ----------

- Programs known as assembler is used to translate assembly language into machine language.
- The input to an assembler is called the source program and the output is a machine language translation(object program).

- **Assembler tasks:**

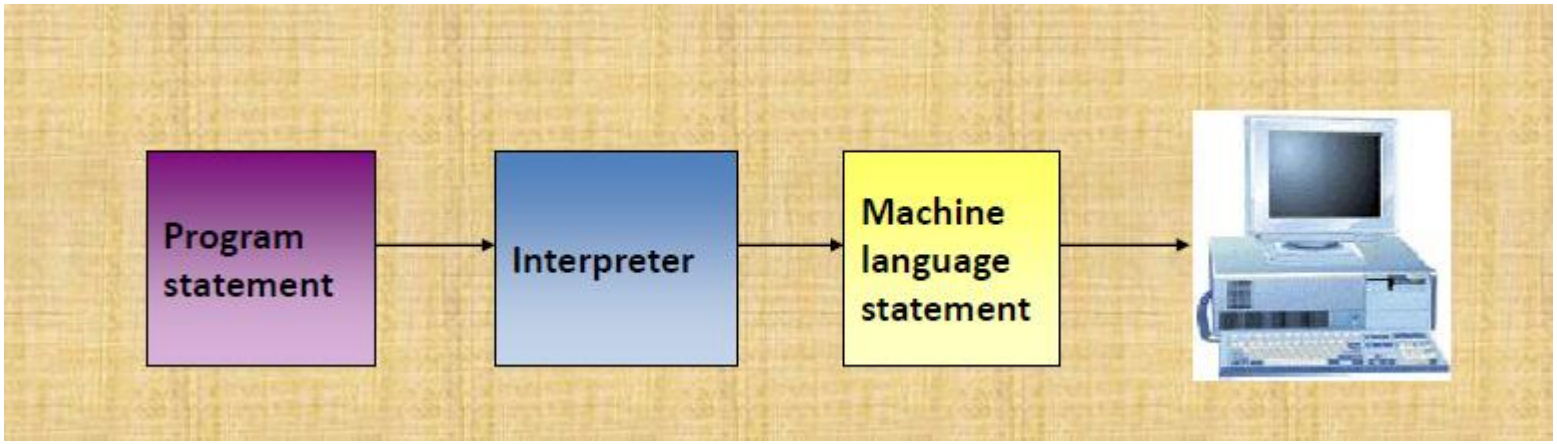
  - Convert symbolic op codes to binary
  - Convert symbolic addresses to binary
  - Perform assembler services requested by the pseudo-ops
  - Put translated instructions into a file for future use

Assembler Task



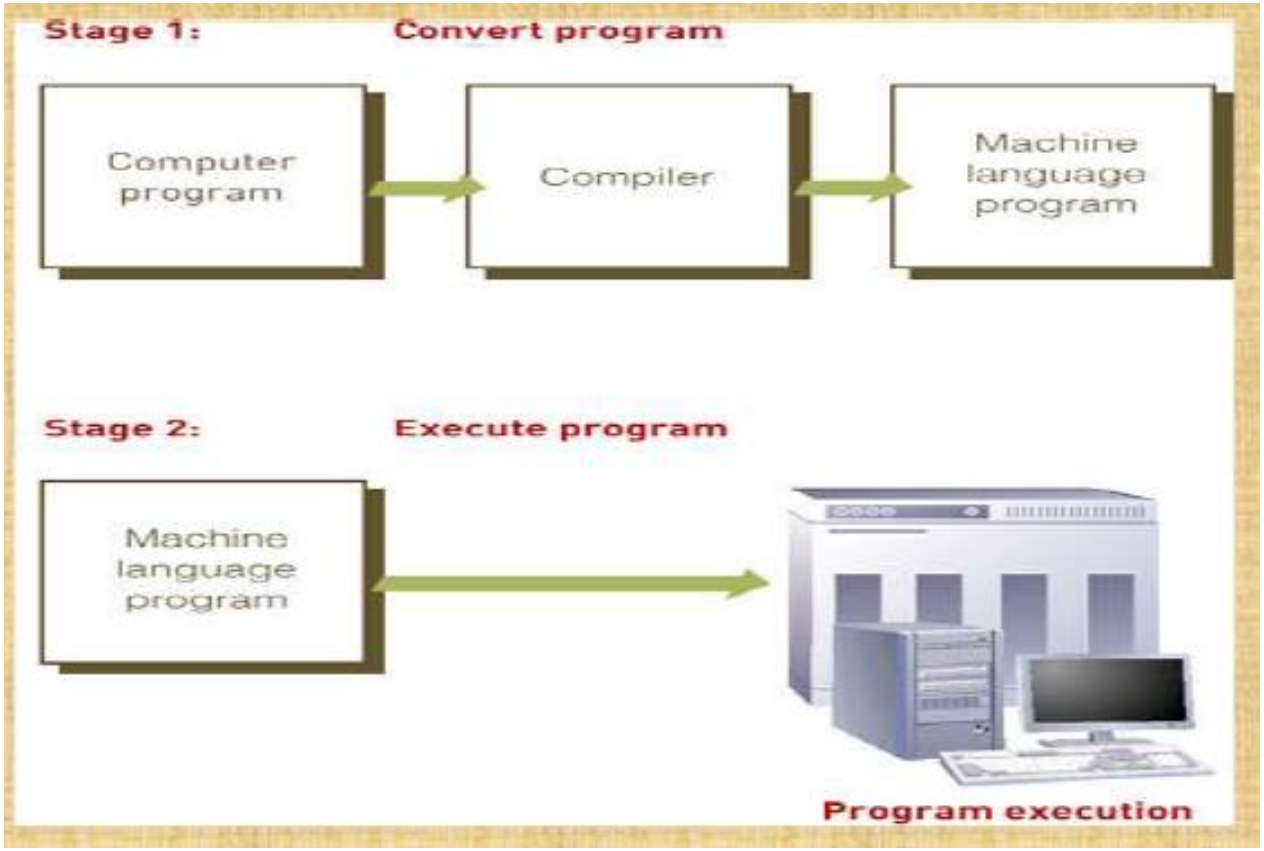
Interpreter

- A language translator that translates one program statement at a time into machine code.



Compiler

A language translators that converts a complete
Program into machine language to produce a program that the computer can Process.



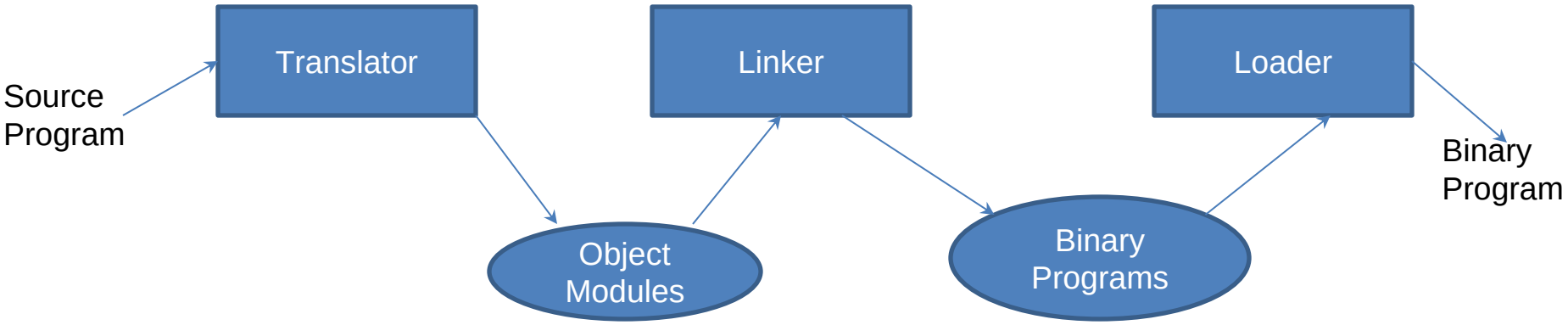
Macro Processor

- It permits the programmer to define an abbreviation for a part of his program and use the abbreviation in our program.
- A macro represents a commonly used group of statements in the source programming language.
- The macro processor replaces each macro instruction with the corresponding group of source language statements. This is called expanding the macros.
- Eg: RDBUFF and WRBUFF

Linkers

Steps in program Execution

- **Translation**
- **Linking**
- **Relocation**
- **Loading**

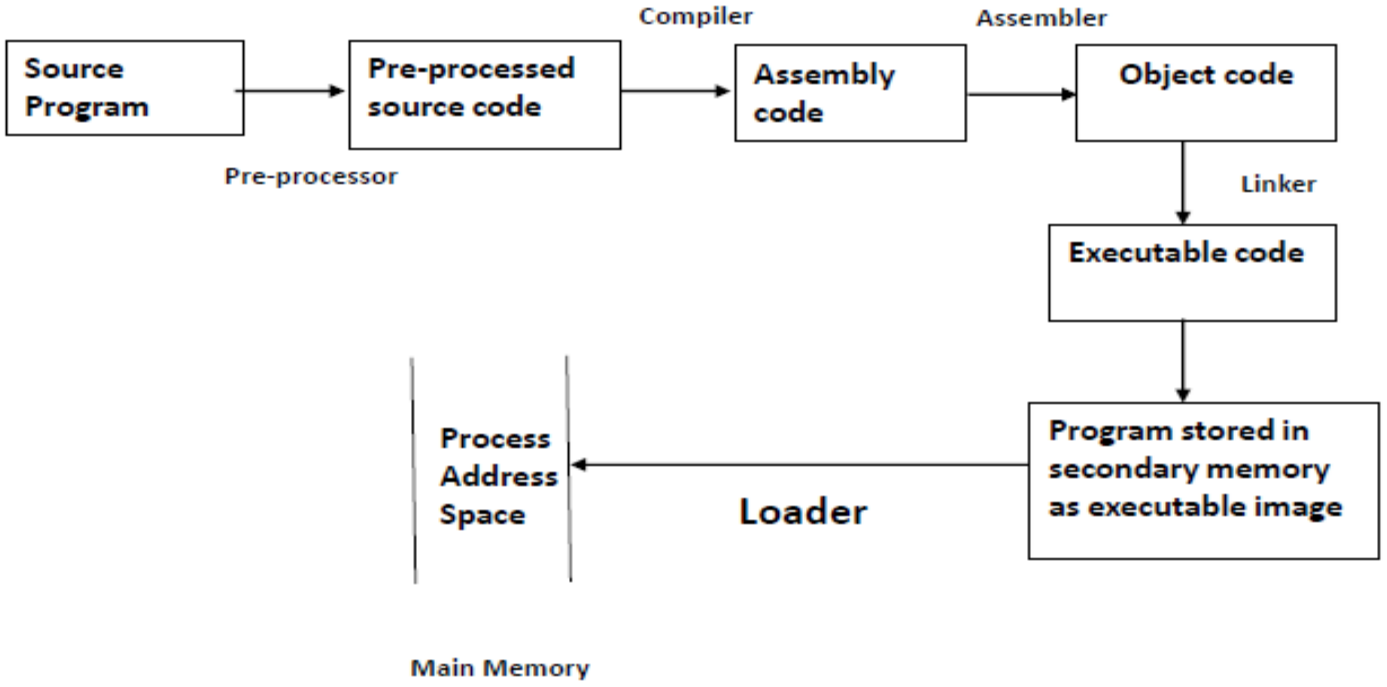


Translated Address (Translated origin)

Linked Address (Linked origin)

Load Time Address (Load origin)

Loader


Source Program
Pre-processed source code
Compiler
Assembly code
Assembler
Object code
Pre-processor
Linker
Executable code
Program stored in secondary memory as executable image
Loader
Process Address Space
Main Memory

Loaders

- Functions of loader:
  1. Allocation
  2. Loading
  3. Relocation
  4. Linking

e.g.

Bootstrap loader, IBM OS/360

Loader

- Performs the loading function.
- Process of placing the program into memory for execution
- Responsible for initiating the execution of the process

Debugger

- A debugger is a software program used to test and find bugs (errors) in other programs .
- A debugger is also known as a debugging tool.
- There are two types of debuggers :
- CorDBG (command-line debugger) – in this , compilation of the original c# file using the debug switch is a must.
- DbgCLR (graphic debugger) – used by Visual Studio .NET

List of Debuggers

- Some widely used debuggers are:
- Firefox JavaScript debugger
- GDB - the GNU debugger
- LLDB
- Microsoft Visual Studio Debugger
- Valgrind
- WinDbg
- Eclipse debugger API used in a range of IDEs : 1. Eclipse IDE (Java) 2. Nodeclipse (JavaScript)
- WDW, the OpenWatcom debugger

Text Editor

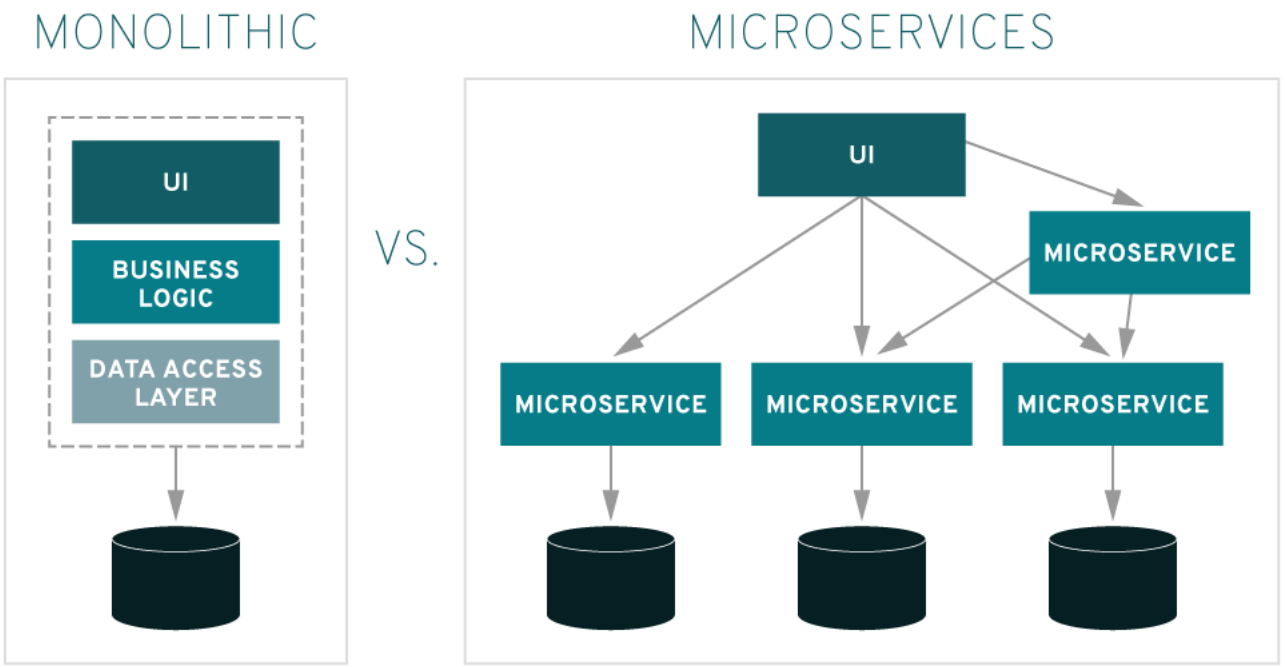
- Primary interface to the computer for all type of “knowledge workers”.
- They compose, organize, study, and manipulate computer-based information.
- A text editor allows you to edit a text file (create, modify etc…).
- The common editing features are:
  - Moving the cursor,
  - Deleting
  - Replacing
  - Pasting
  - Searching
  - Searching and replacing,
  - Saving and loading, and,
  - Miscellaneous(e.g. quitting)

Examples

- Windows OS - Notepad, WordPad, Microsoft Word, and text editors.
- UNIX OS - vi, emacs, jed, pico.
- Gui based editors
- • Gedit gvim
- Nedit
- Tea
- subtime

Microservices

- Microservices are an architectural approach to building applications. As an architectural framework, microservices are distributed and loosely coupled, so one team's changes won't break the entire app.
- The benefit to using microservices is that development teams are able to rapidly build new components of apps to meet changing business needs.



Microservices

- **Microservices** are a software development technique
- Microservices - also known as the micro service architecture
- A variant of the service-oriented architecture (SOA) structural style that arranges an application as a collection of loosely coupled services.
- In a microservices architecture, services are fine-grained and the protocols are lightweight.
- It is an architectural style that structures an application as a collection of services that are:
  - Highly maintainable and testable
  - Loosely coupled
  - Independently deployable
  - Organized around business capabilities
  - Owned by a small team

Containers

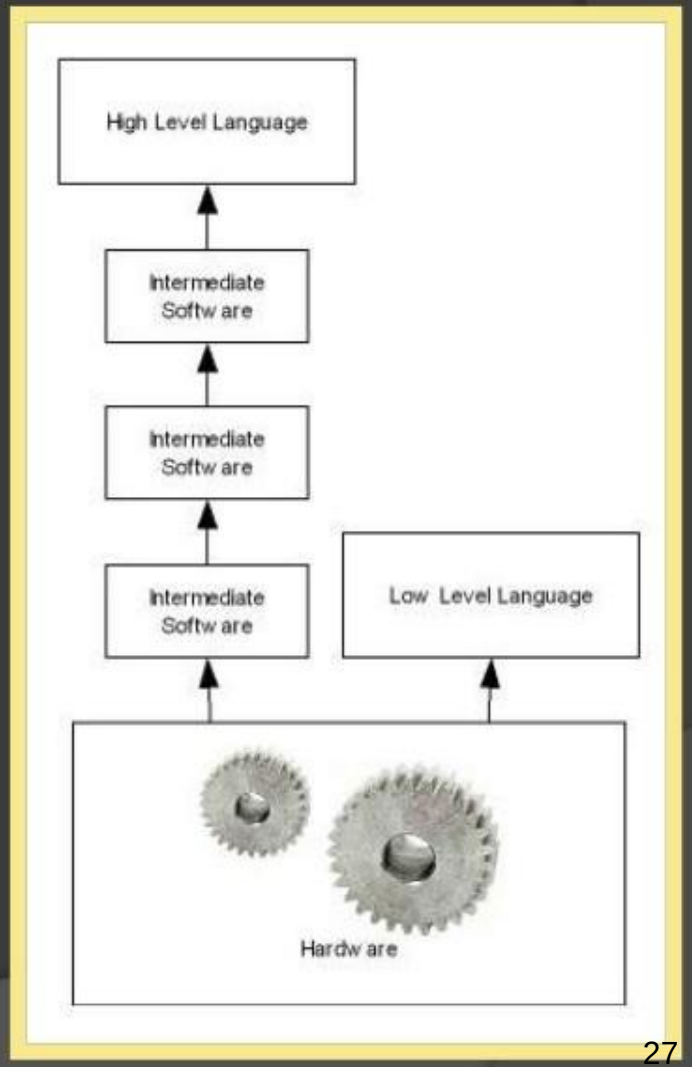
- A **microservice** is an application with a single function, such as routing network traffic, making an online payment or analyzing a medical result.
- **Containers** are easily packaged, lightweight and designed to run anywhere. Containers offer a logical packaging mechanism in which applications can be abstracted from the environment in which they actually run.
- Multiple **containers** can be deployed in a single VM.

- Eg. Netflix has a widespread architecture that has evolved from monolithic to SOA. It receives more than one billion calls every day, from more than 800 different types of devices, to its streaming-video API. Each API call then prompts around five additional calls to the backend service.
- Amazon has also migrated to microservices. They get countless calls from a variety of applications—including applications that manage the web service API as well as the website itself—which would have been simply impossible for their old, two-tiered architecture to handle.

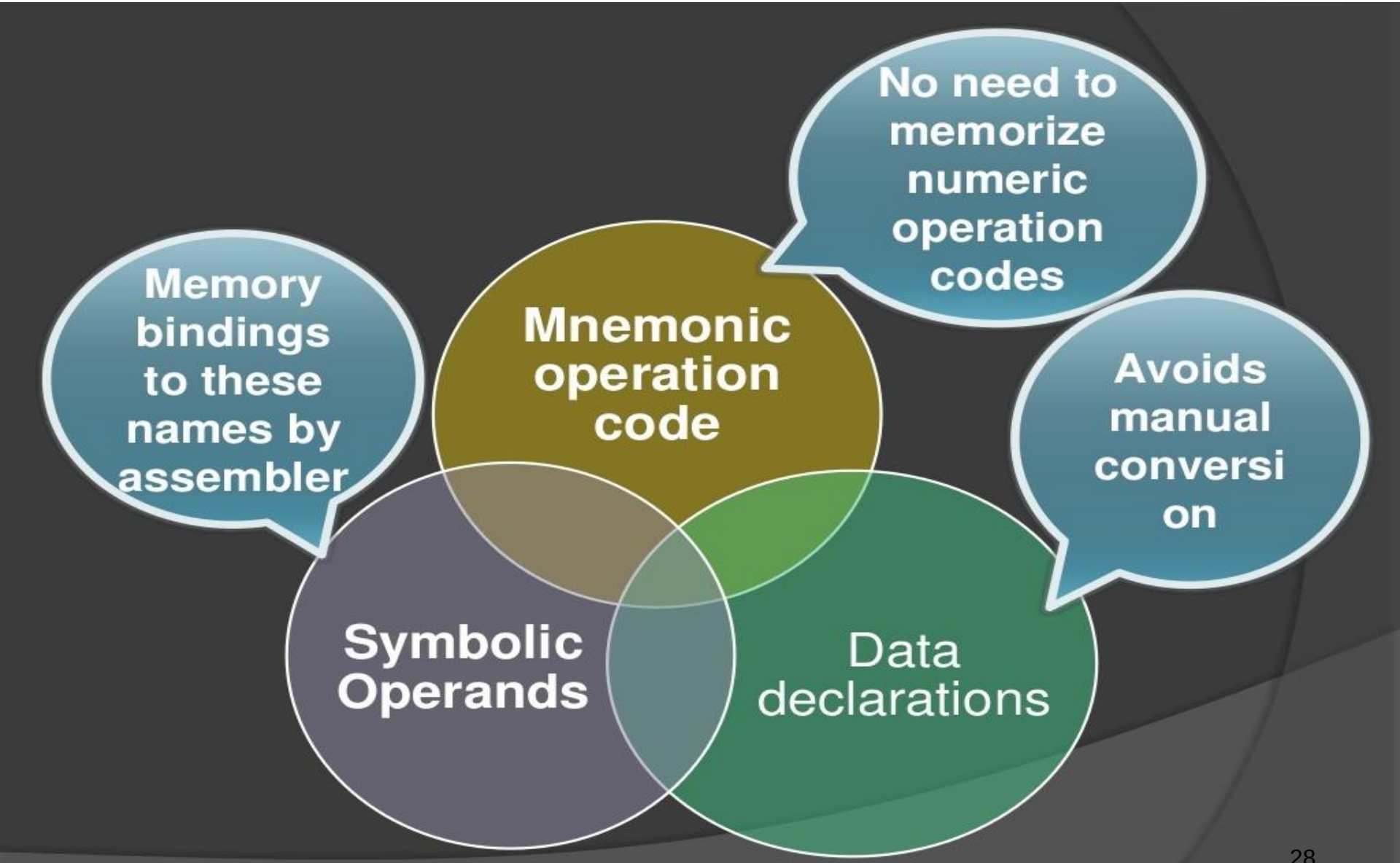
Assembler

Assembly language

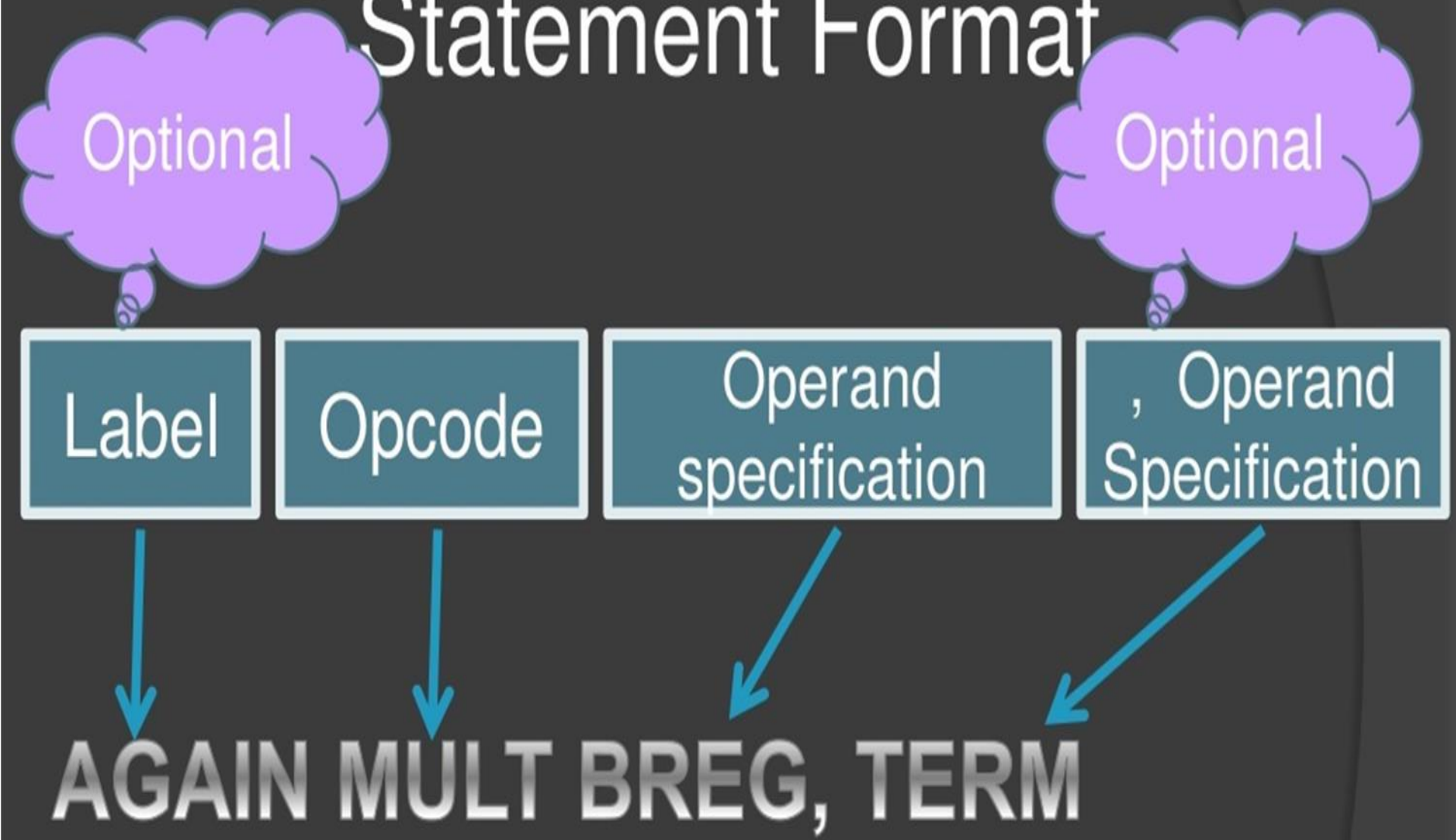
- Machine dependant
- Low level programming language



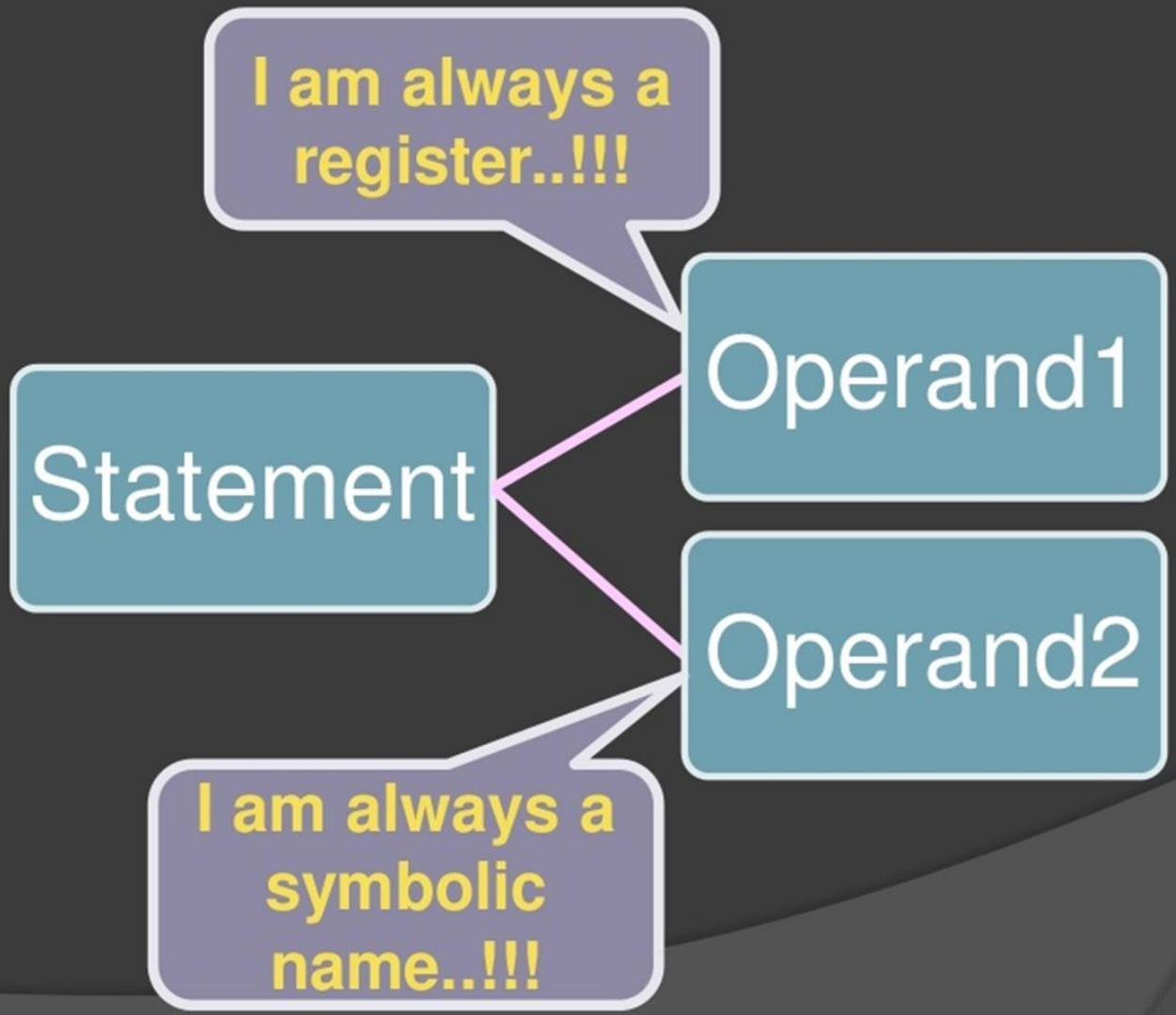
Elements Of ALP



Statement Format

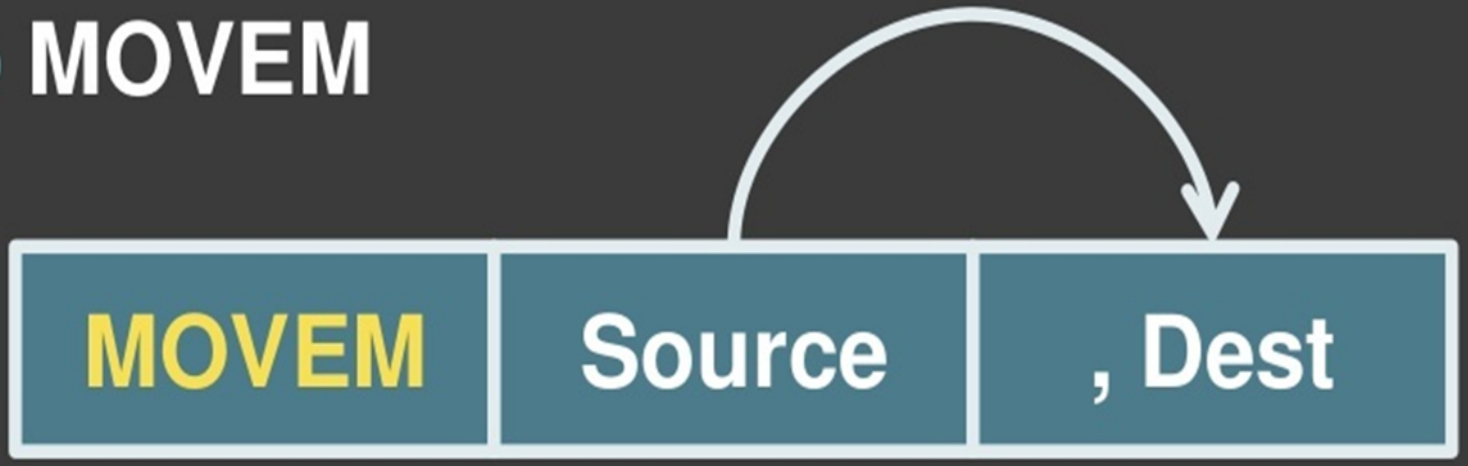


A simple assembly language



MOVER and MOVEM

- **MOVEM**



- **MOVER**

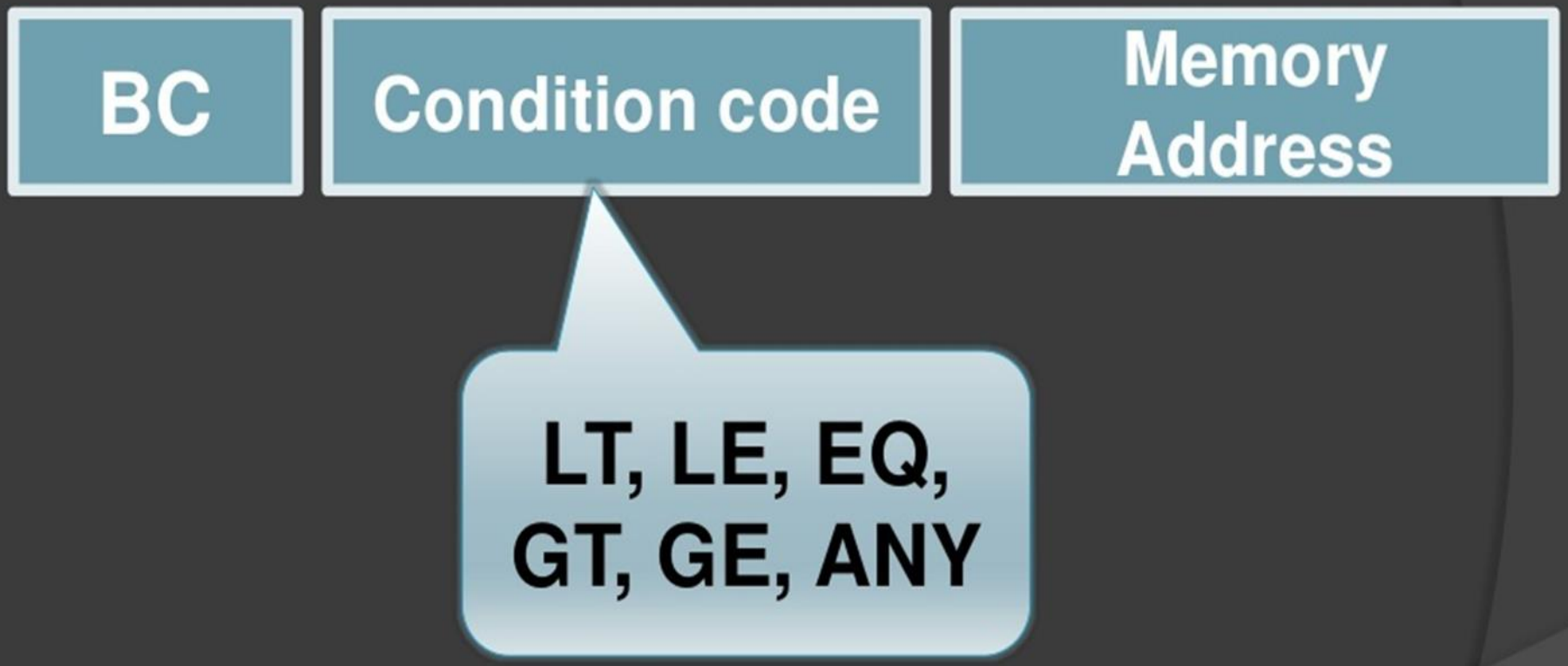
Operand specification

Symbolic name	+ (Displacement)	Index register

Mnemonic Operation Codes

Instruction Opcode	Assembly Mnemonic	Remarks
00	STOP	Stops execution
01	ADD	First operand is
02	SUB	Modified
03	MULT	
04	MOVER	Register ← memory move
05	MOVEM	Memory ← register move
06	COMP	Sets condition code
07	BC	Branch on Condition
08	DIV	Analogous to SUB
09	READ	Performs reading and
10	PRINT	printing

Syntax for BC



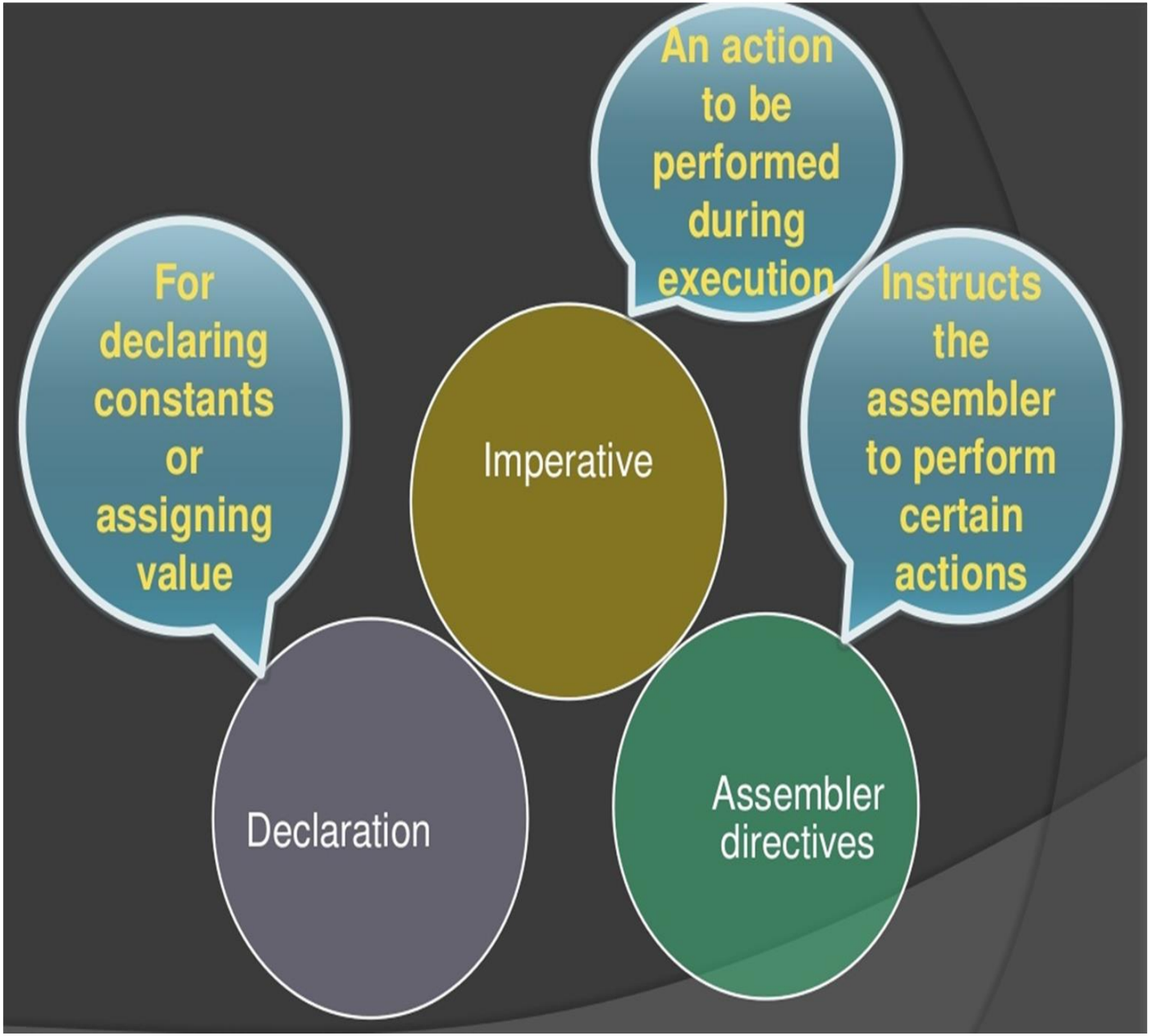
What if we want to have an unconditional jump?

Machine instruction format and example

Example ALP and its equivalent MLP

```
          START   101
          READ    N                    101) + 09 0 113
          MOVER   BREG, ONE            102) + 04 2 115
          MOVEM   BREG, TERM           103) + 05 2 116
AGAIN     MULT    BREG, TERM           104) + 03 2 116
          MOVER   CREG, TERM           105) + 04 3 116
          ADD     CREG, ONE            106) + 01 3 115
          MOVEM   CREG, TERM           107) + 05 3 116
          COMP    CREG, N              108) + 06 3 113
          BC      LE,   AGAIN          109) + 07 2 104
          MOVEM   BREG, RESULT         110) + 05 2 114
          PRINT   RESULT               111) + 10 0 114
          STOP                         112) + 00 0 000
N         DS      1                    113)
RESULT    DS      1                    114)
ONE       DC      '1'                  115)
TERM      DS      1                    116)
          END
```

Statement Class for an ALP



Declaration Statements

DS

(Declare Storage)

- Reserves area of memory and associates names with them
- Example : A DS 1

DC

(Declare constant)

- Construct memory words containing constants
- ONE DC '1'

What is the use of constants?

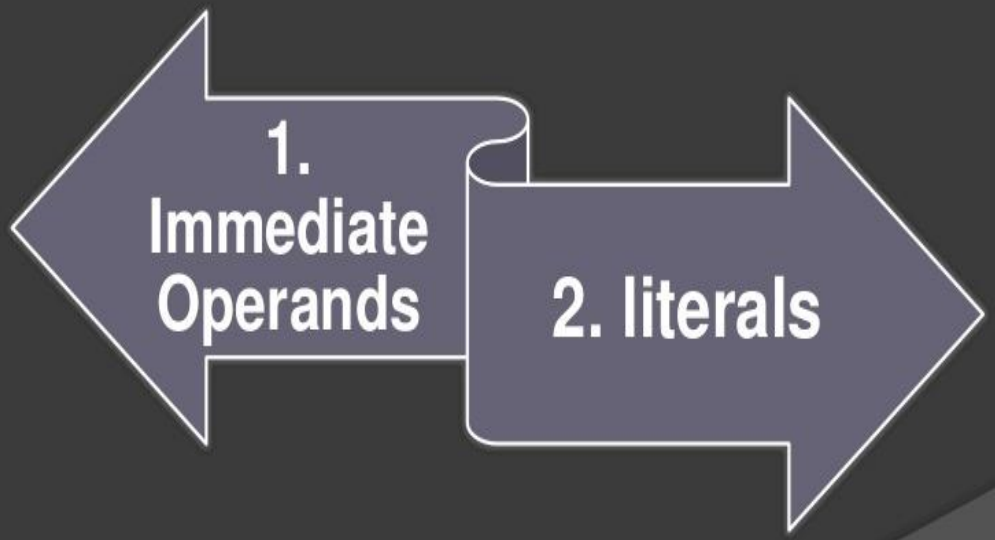
- DC doesn't really implement the constants because…

- These values are not protected by assembler
- They may be changed by moving the new value in that memory word.

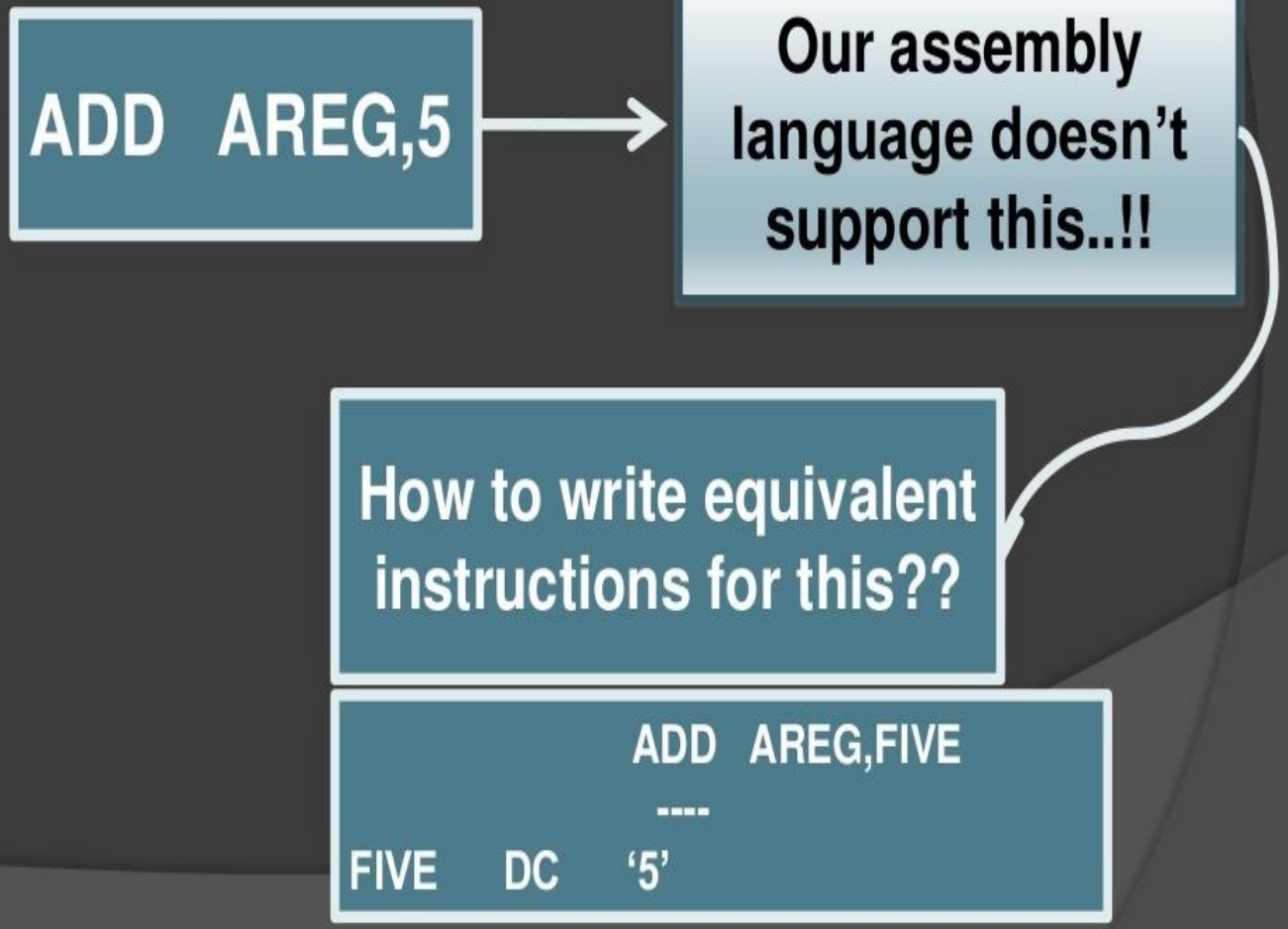
```
ONE   DC  '1'

MOVEM BREG,ONE
```

Similarities with the implementation of constants in HLL



1. A constant as immediate operand



2. Literal

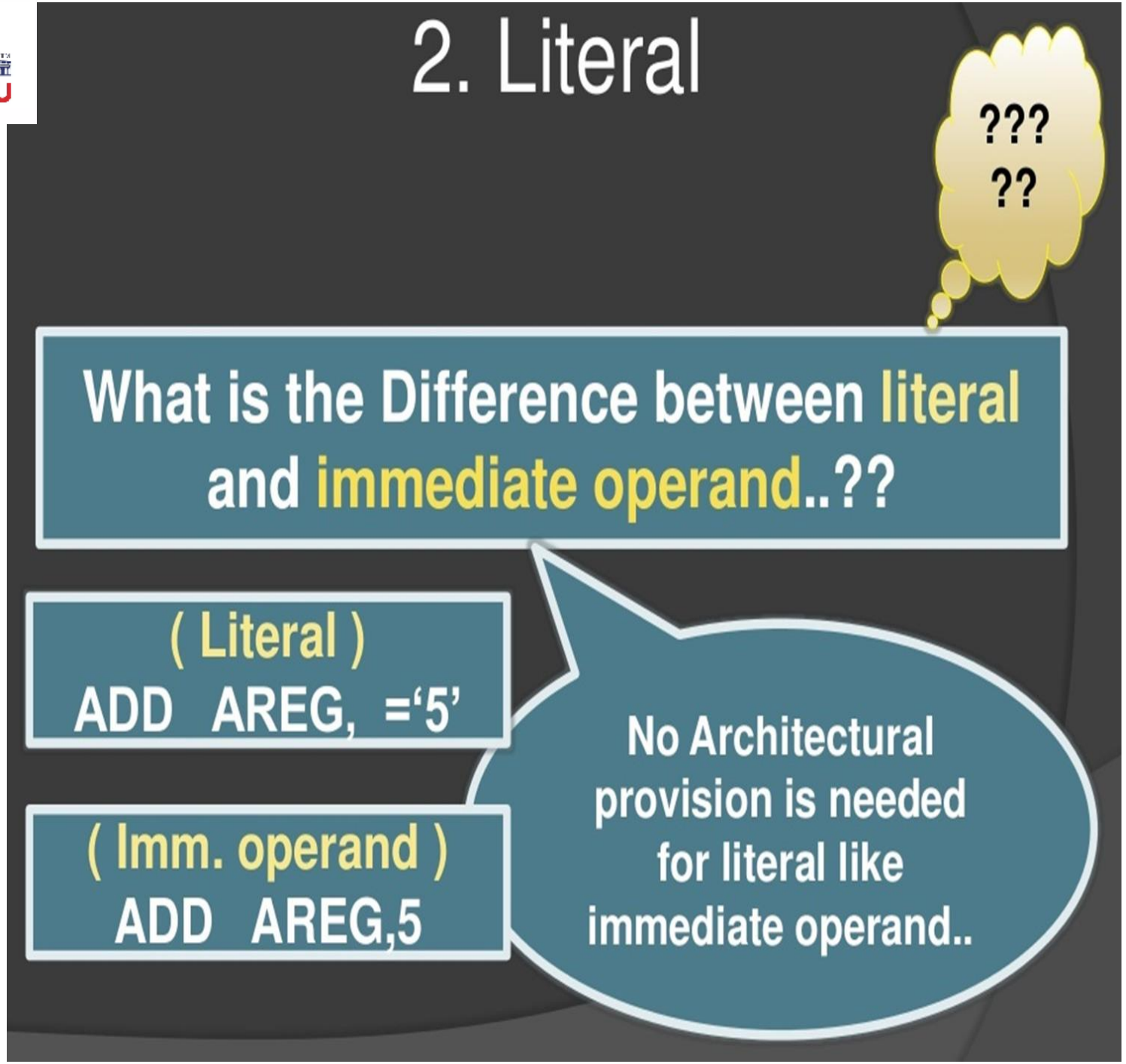
- **Operand** with syntax **= ' value '**

???
??

What is the Difference between literal and constant..??

```
ADD   AREG,  ='5'
```

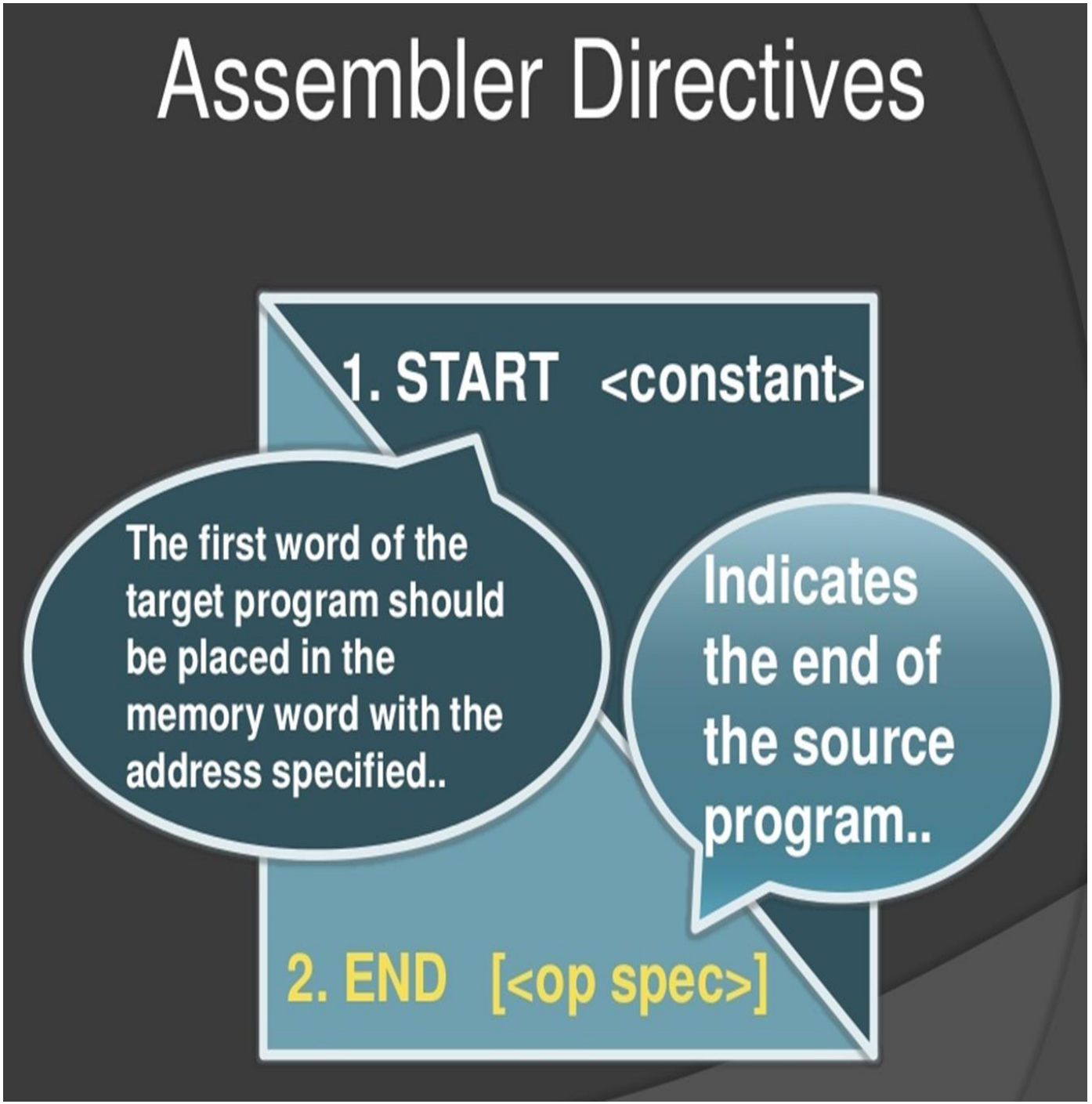
The location of a literal cant be specified. So its value cant be changed like constant...


2. Literal
???
??
What is the Difference between literal and immediate operand..??
(Literal)
ADD AREG, ='5'
(Imm. operand)
ADD AREG,5
No Architectural provision is needed for literal like immediate operand..

Difference between Literal and immediate operand

- Literal is an assembler directive
- Immediate is a machine recognizable data.
- values are obtained from data memory
- Immediate data is within the instructions itself
- Eg.
  - MOV R1, 17 ; mov 17 to reg r1
  - DW 17 ; define a word containing the literal 17

Assembler Directives



Sample Assembly Language Program with its Machine Translation

	START	101		
	READ	N		101) + 09 0 113
	MOVER	BREG,	ONE	102) + 04 2 115
	MOVEM	BREG,	TERM	103) + 05 2 116
AGAIN	MULT	BREG,	TERM	104) + 03 2 116
	MOVER	CREG,	TERM	105) + 04 3 116
	ADD	CREG,	ONE	106) + 01 3 115
	MOVEM	CREG,	TERM	107) + 05 3 116
	COMP	CREG,	N	108) + 06 3 113
	BC	LE,	AGAIN	109) + 07 2 104
	MOVEM	BREG,	RESULT	110) + 05 2 114
	PRINT	RESULT		111) + 10 0 114
	STOP			112) + 00 0 000
N	DS	1		113)
RESULT	DS	1		114)
ONE	DC	'1'		115)
TERM	DS	1		116)
	END			

Advantages of assembly language

- Machine language program needs to be changed drastically if we modify the original program.
- It is more suitable when it is desirable to use specific architectural features of a computer…
- Example – special instructions supported by CPU

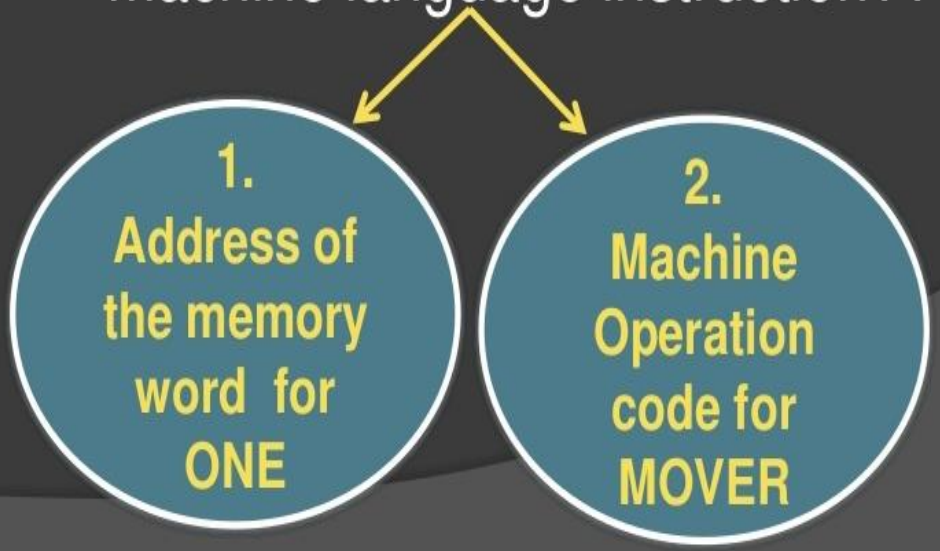
Design Specification of assembler

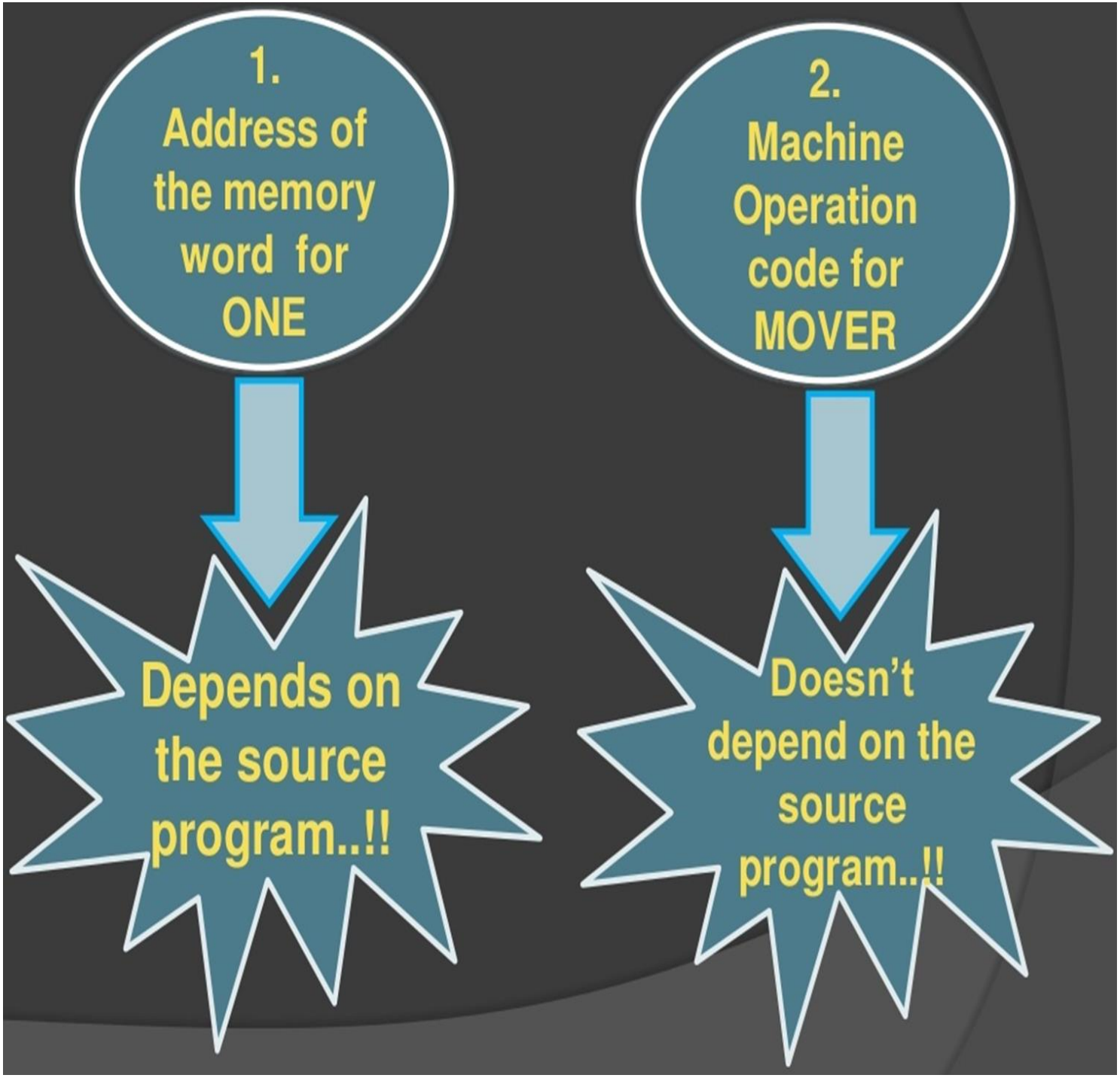
- Identify the information necessary to perform the task
- Design the suitable data structures to record the information
- Determine the processing necessary to obtain and manage the information
- Determine the information necessary to perform the task

Example

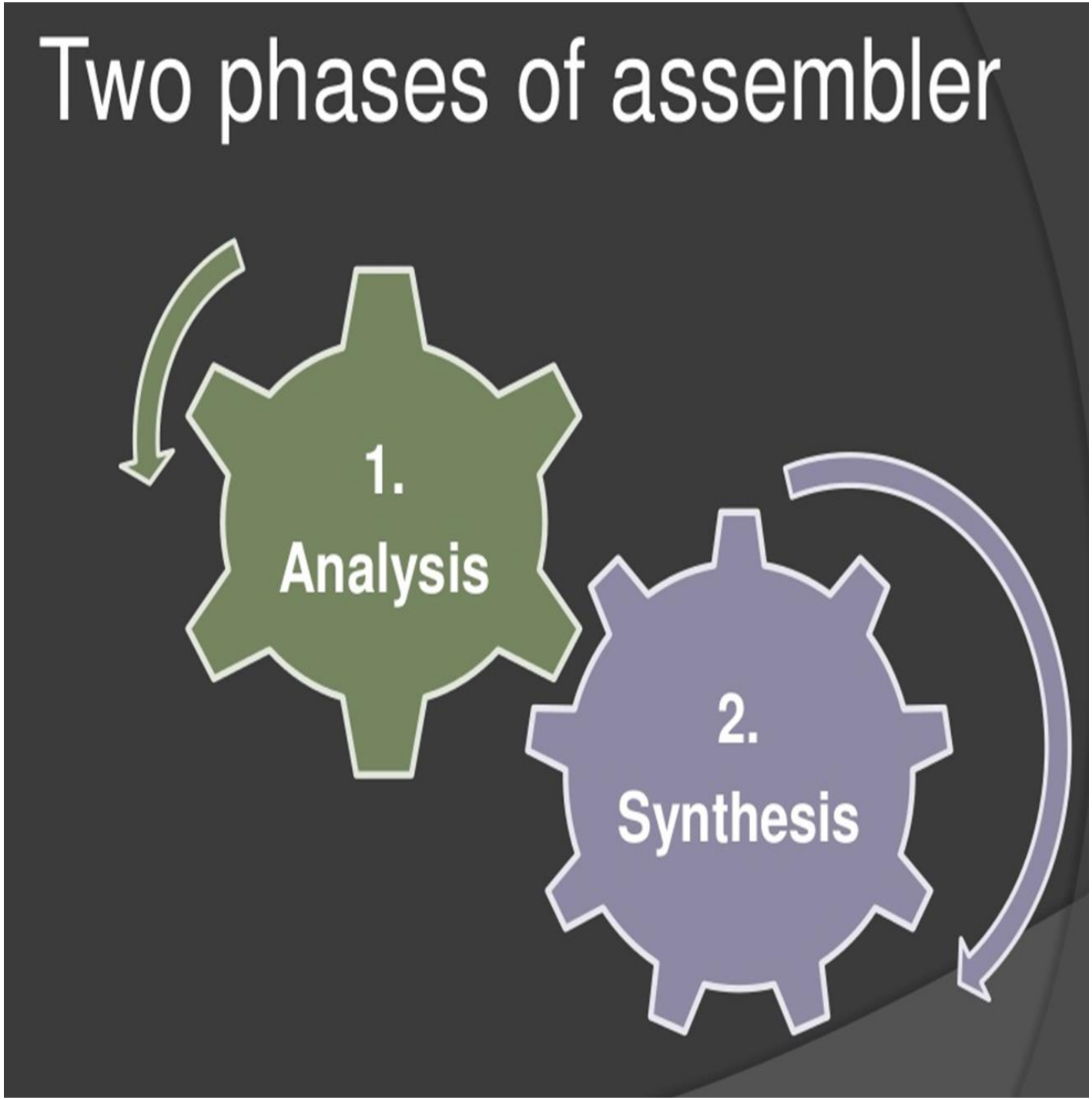
MOVER BREG, ONE

Which information **do we need** to **convert** this instruction in to the equivalent machine language instruction???




1.
Address of the memory word for ONE
2.
Machine Operation code for MOVER
Depends on the source program..!!
Doesn't depend on the source program..!!

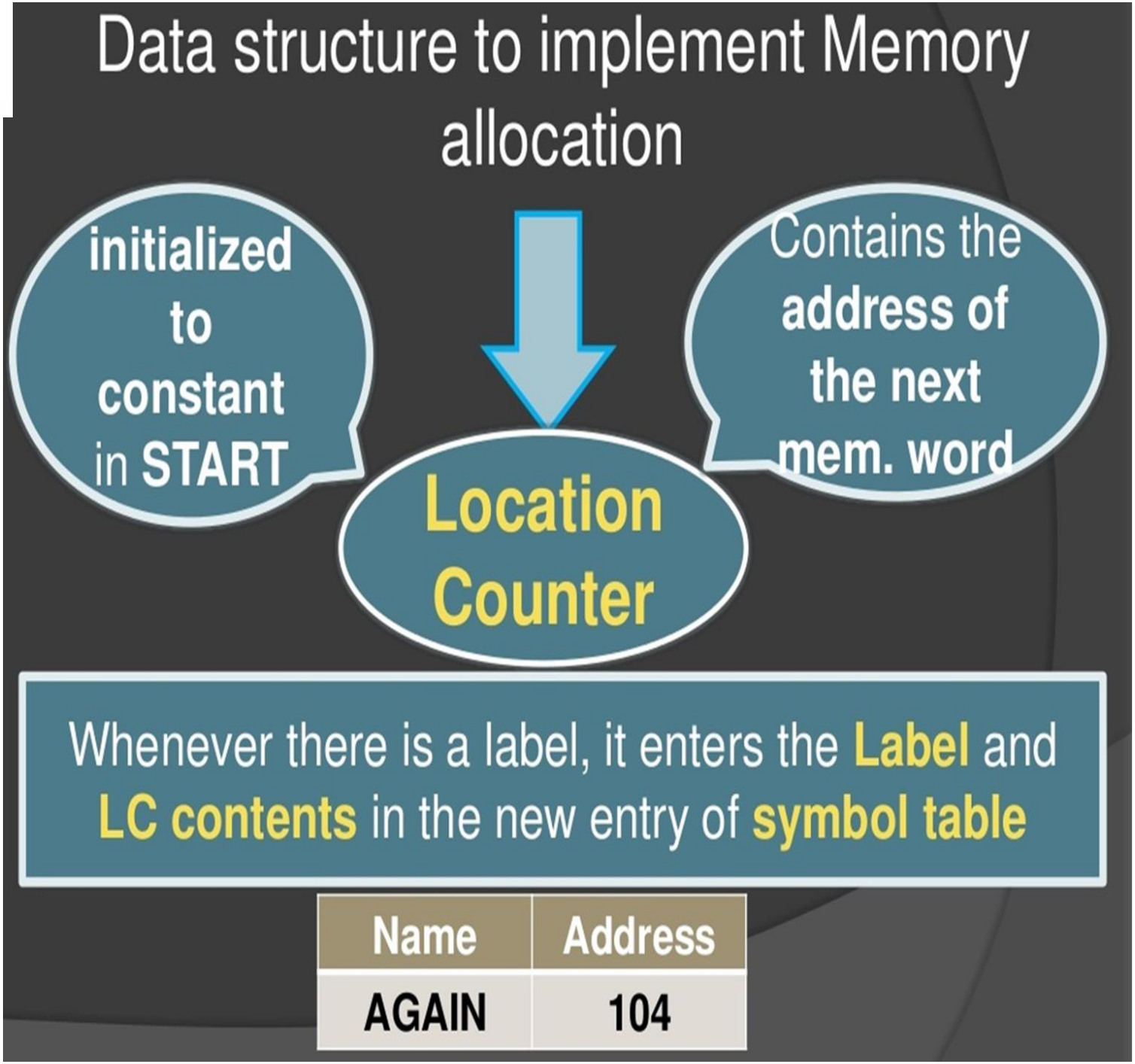
Two phases of assembler

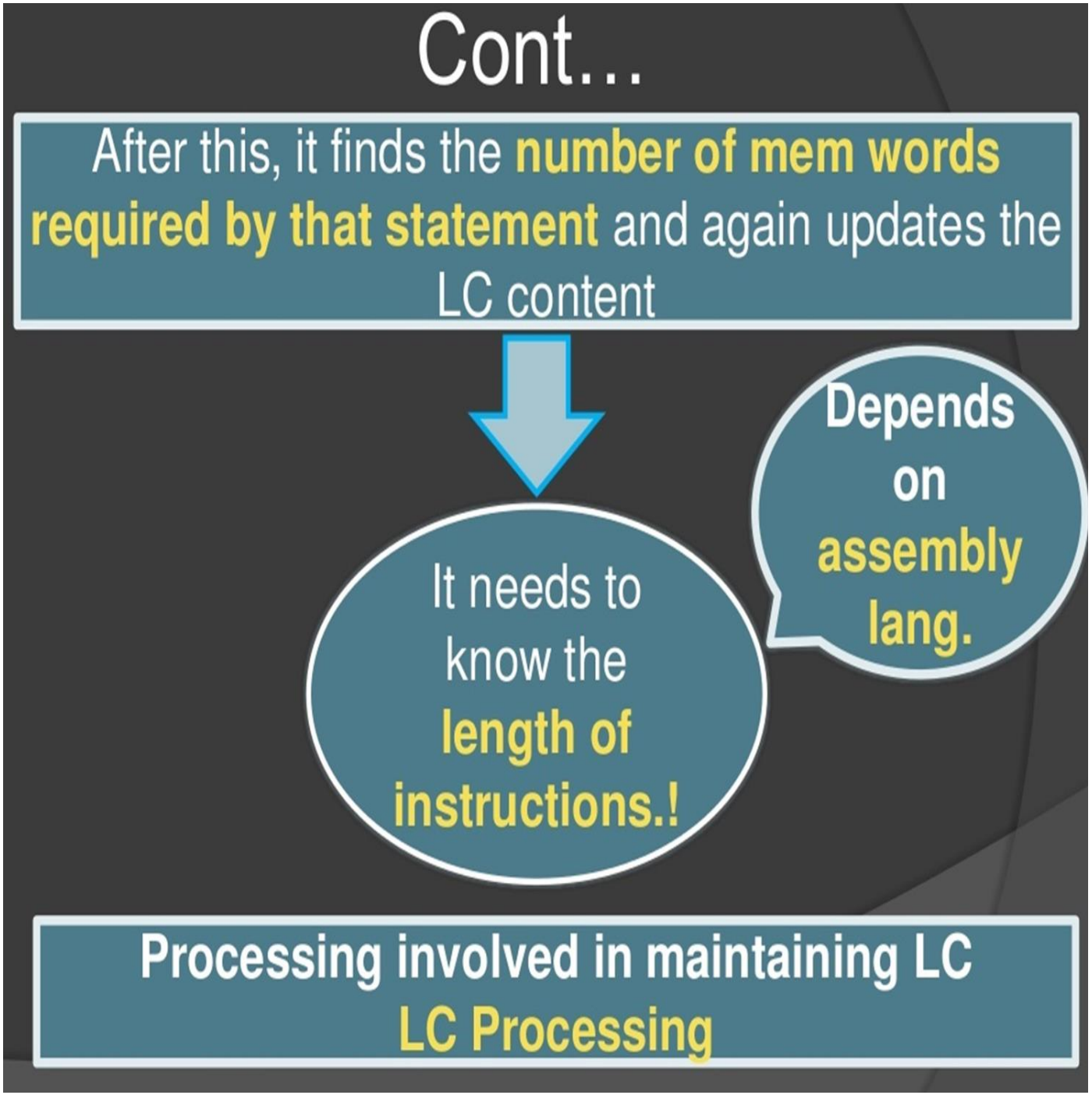


Analysis phase

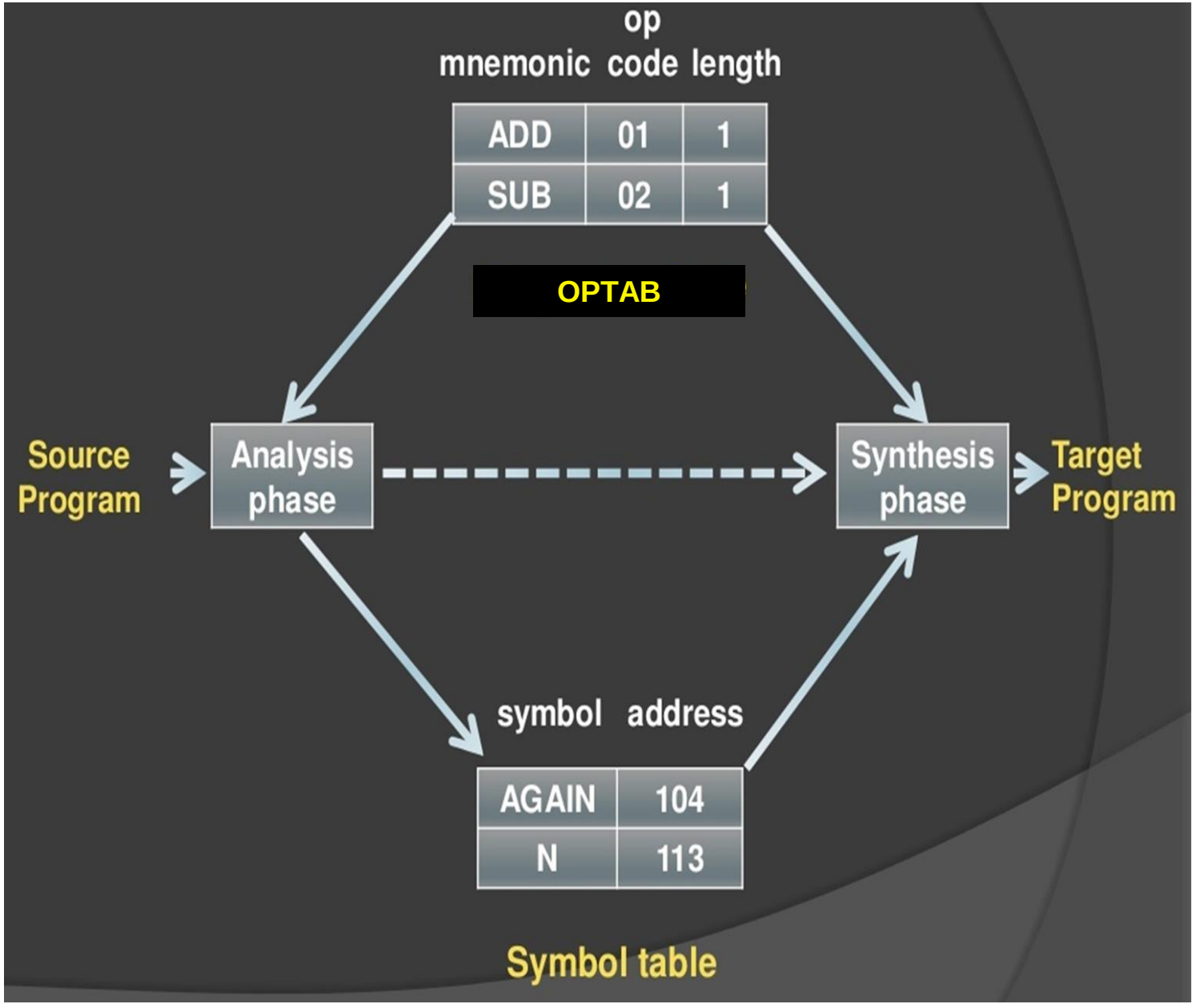
- Main Task : Building of **Symbol table**
- For this, it must determ... with which the symbolic nam...
- To determine the address of a particular symbolic name, we must fix the address of all elements preceding it

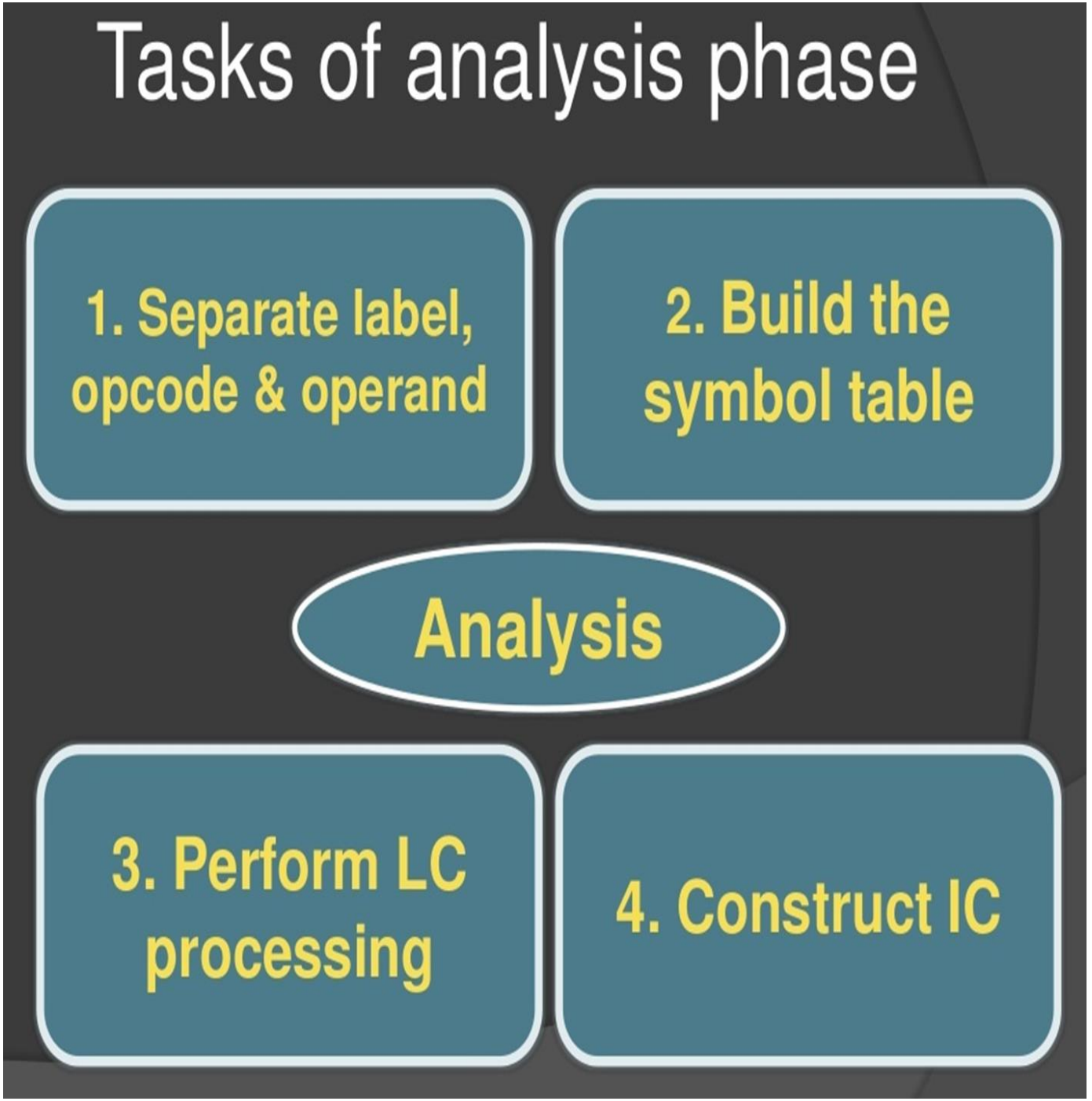
Memory allocation..


Data structure to implement Memory allocation
initialized to constant in START
Location Counter
Contains the address of the next mem. word
Whenever there is a label, it enters the Label and LC contents in the new entry of symbol table
Name
Address
AGAIN
104

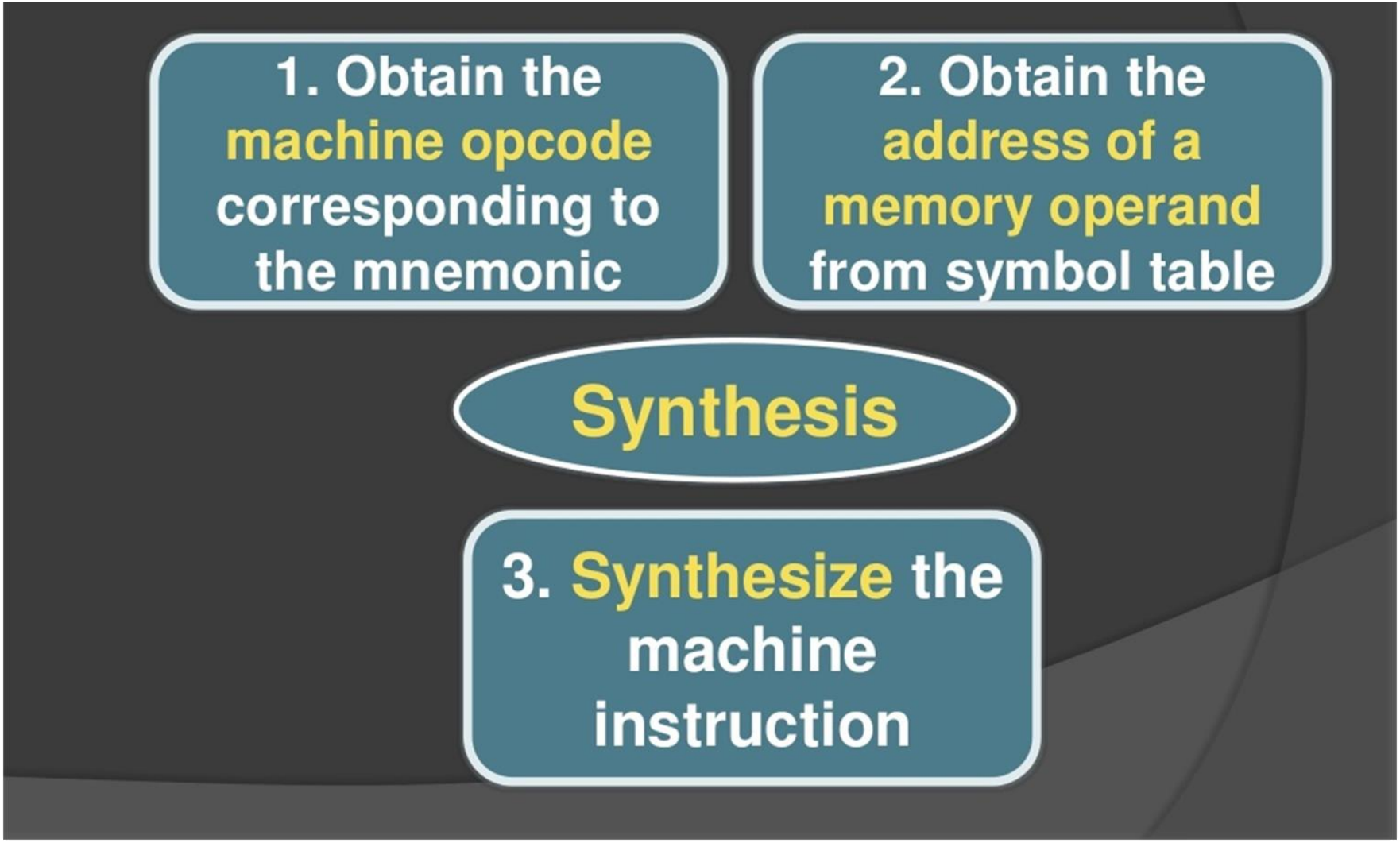

Cont...
After this, it finds the number of mem words required by that statement and again updates the LC content
Depends on assembly lang.
It needs to know the length of instructions.!
Processing involved in maintaining LC
LC Processing

Data Structures For Assembler

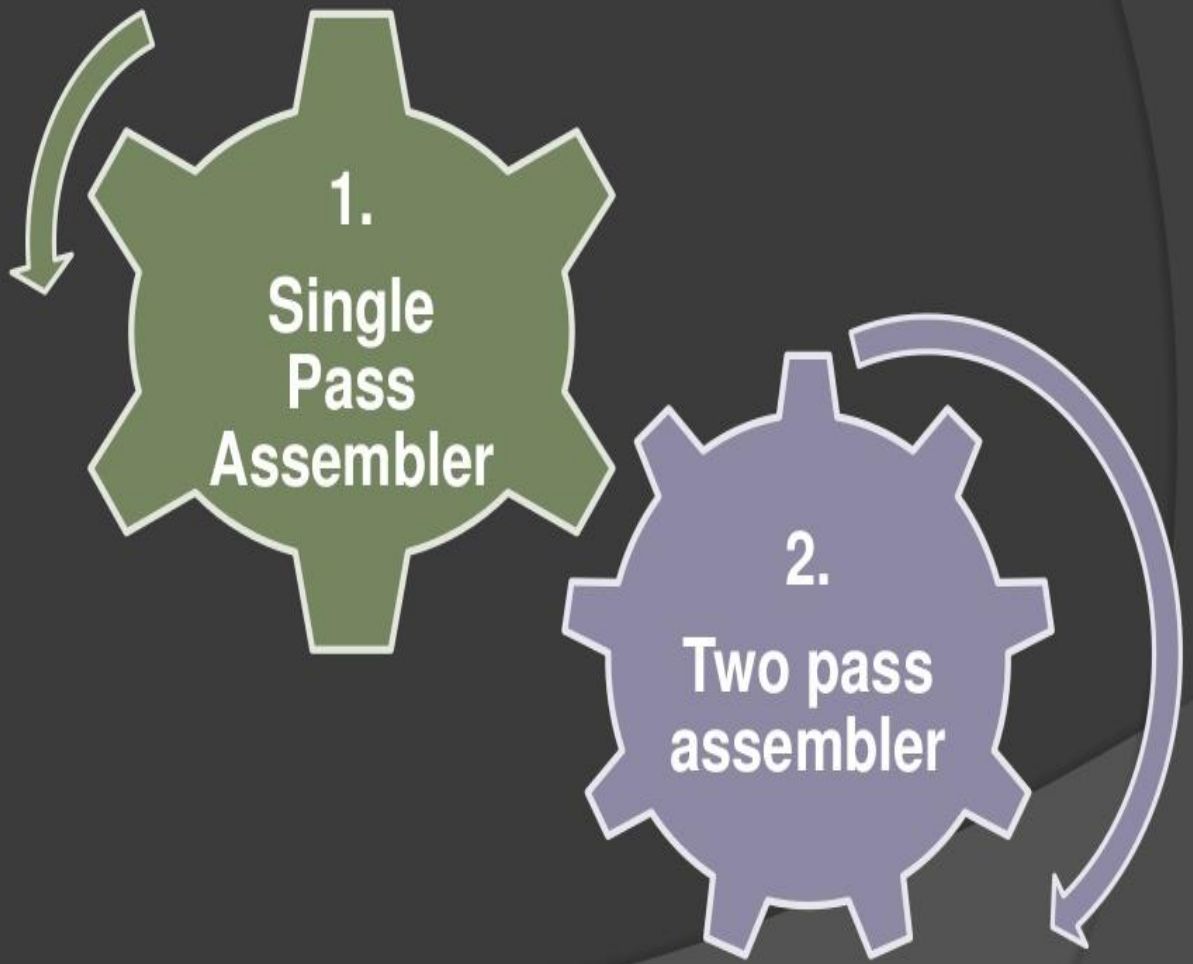


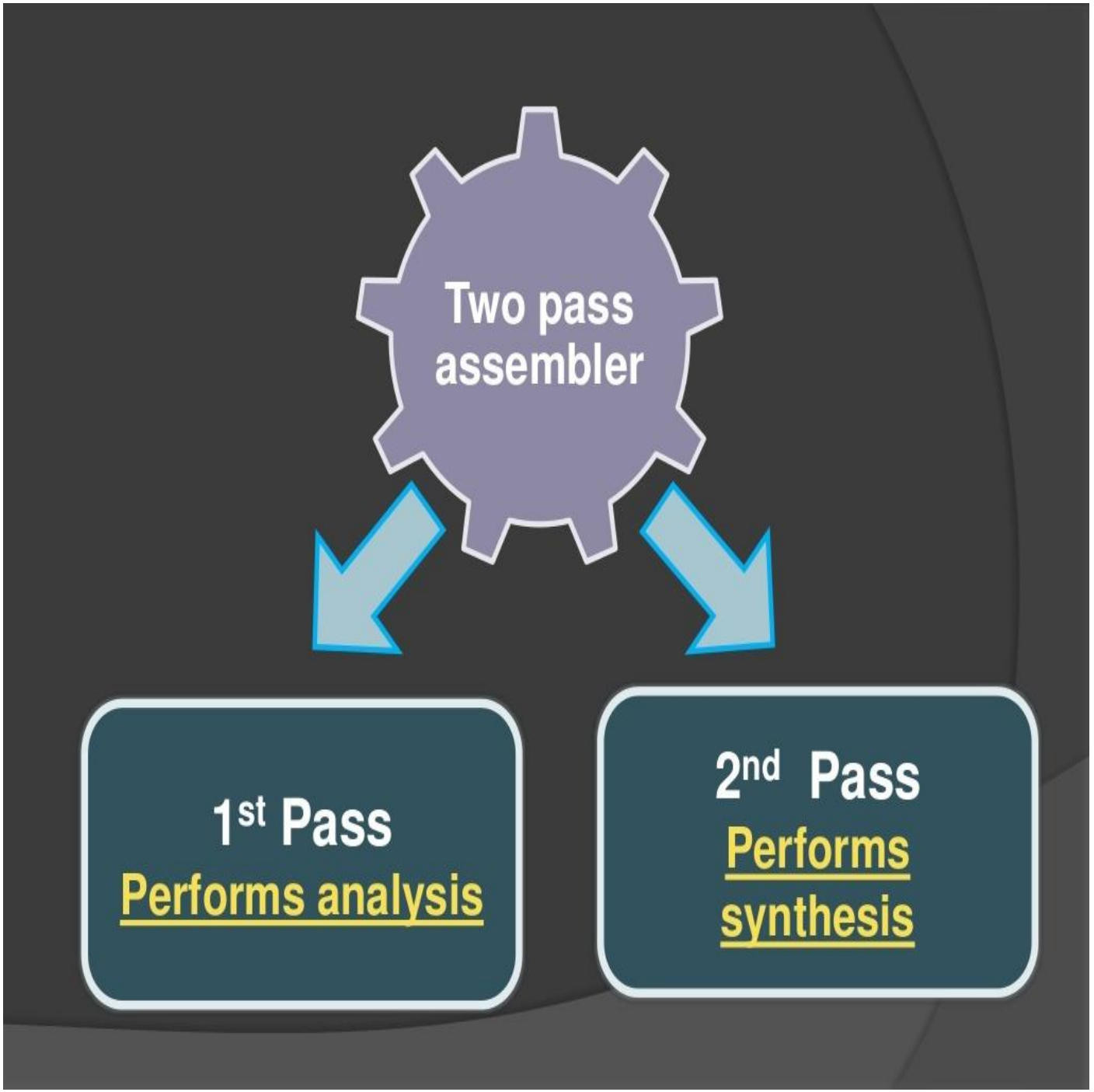

Tasks of analysis phase
1. Separate label, opcode & operand
2. Build the symbol table
Analysis
3. Perform LC processing
4. Construct IC

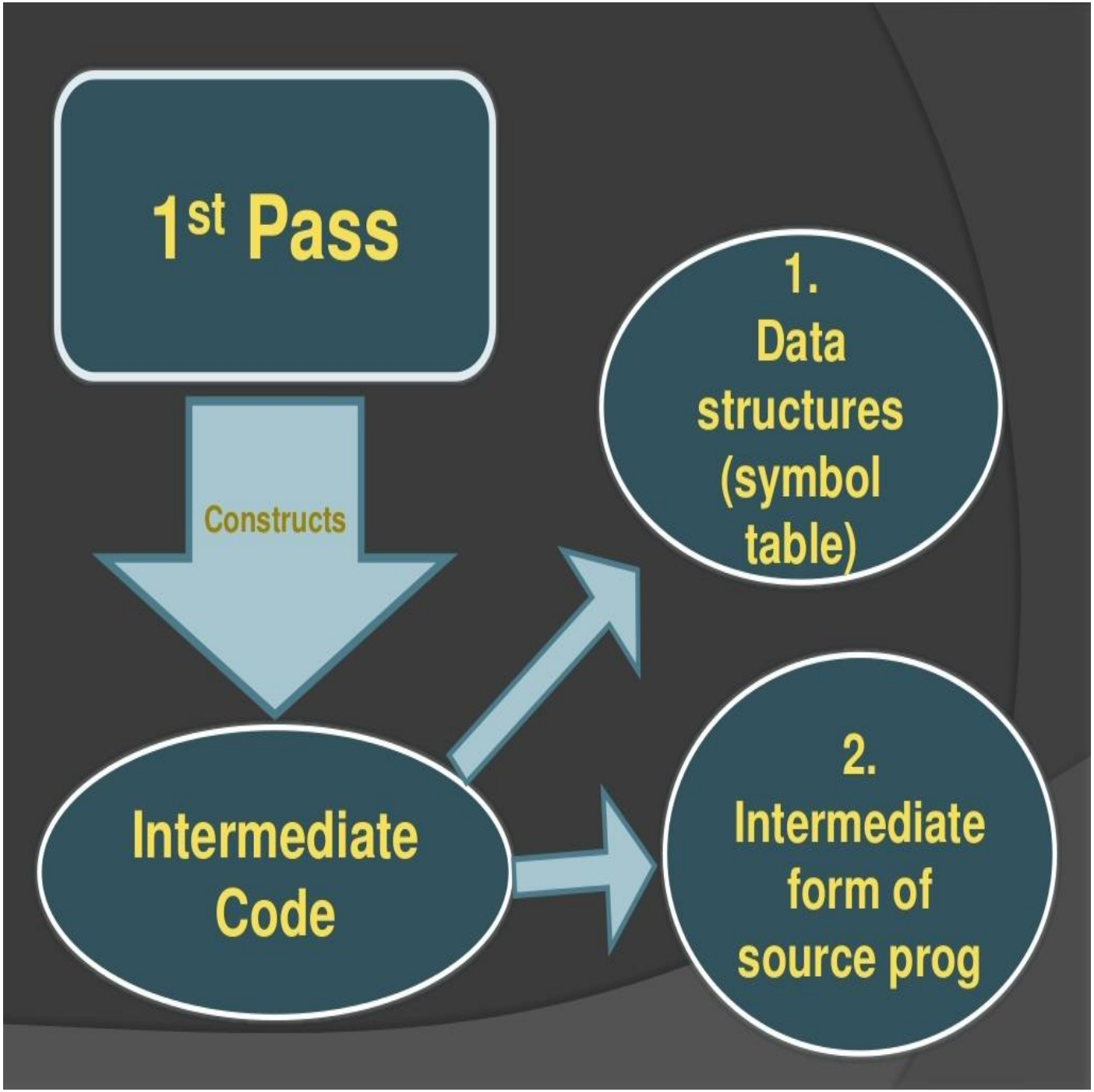
Tasks of Synthesis Phase

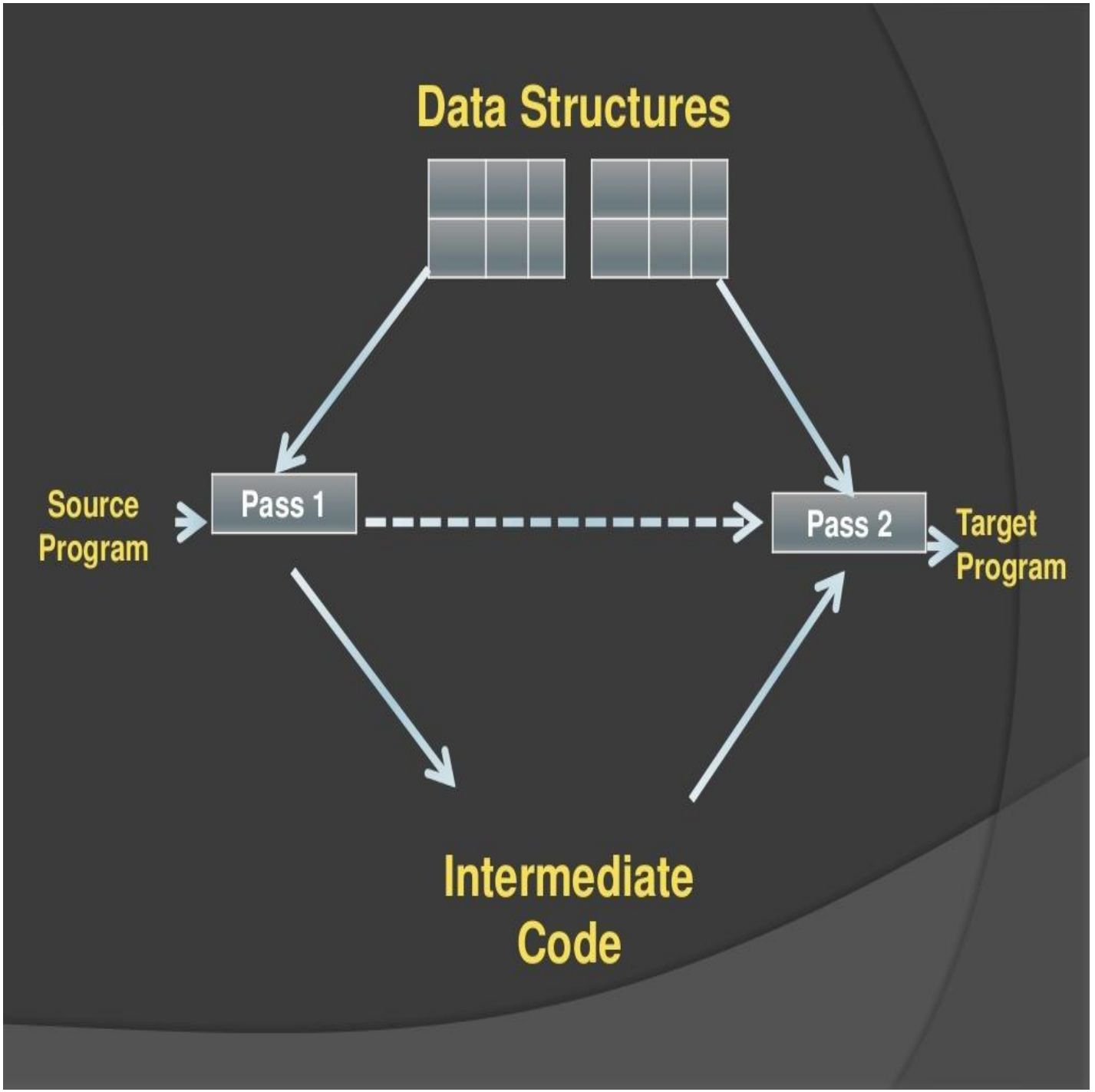


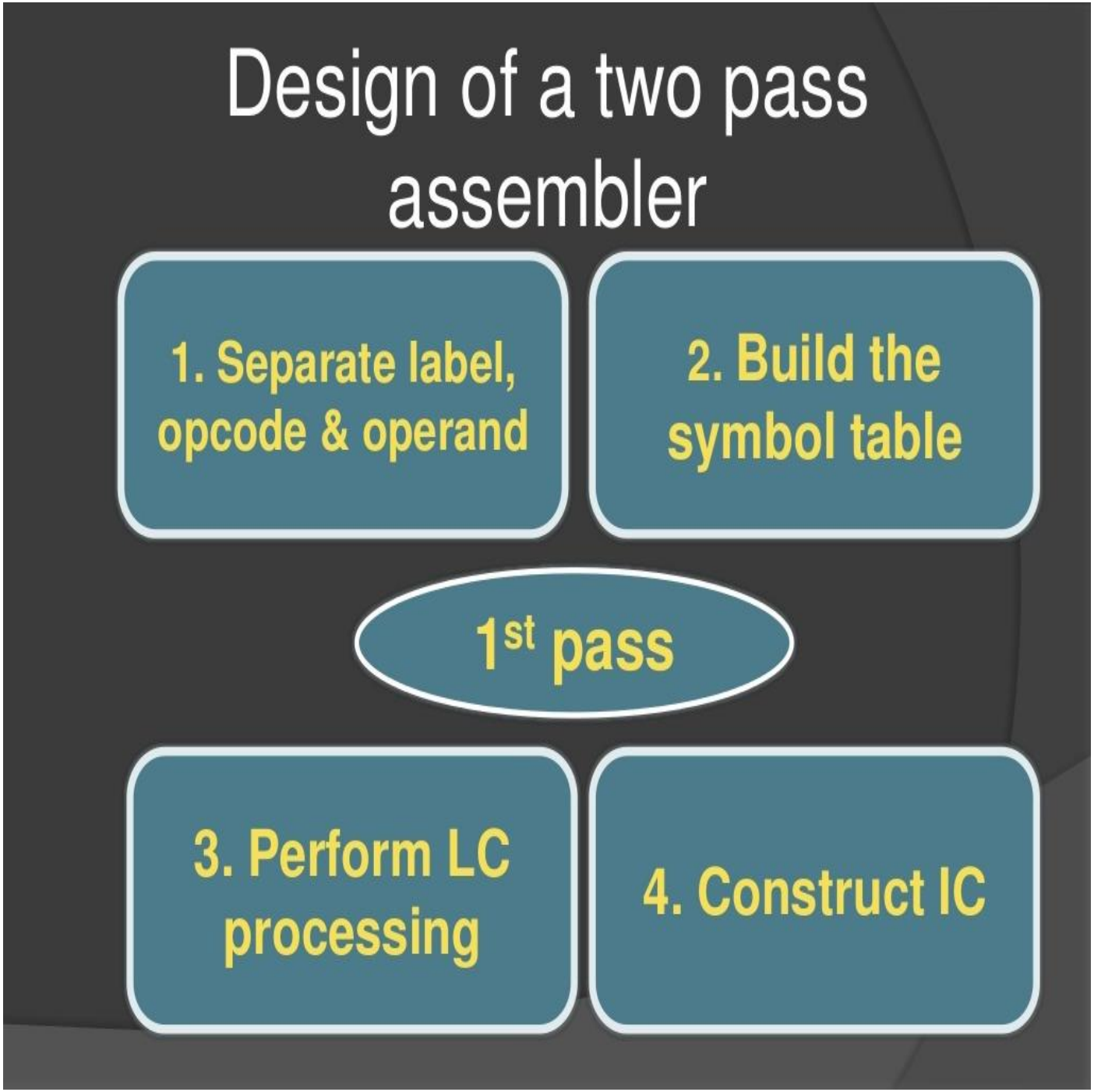
Pass structure of Assembler

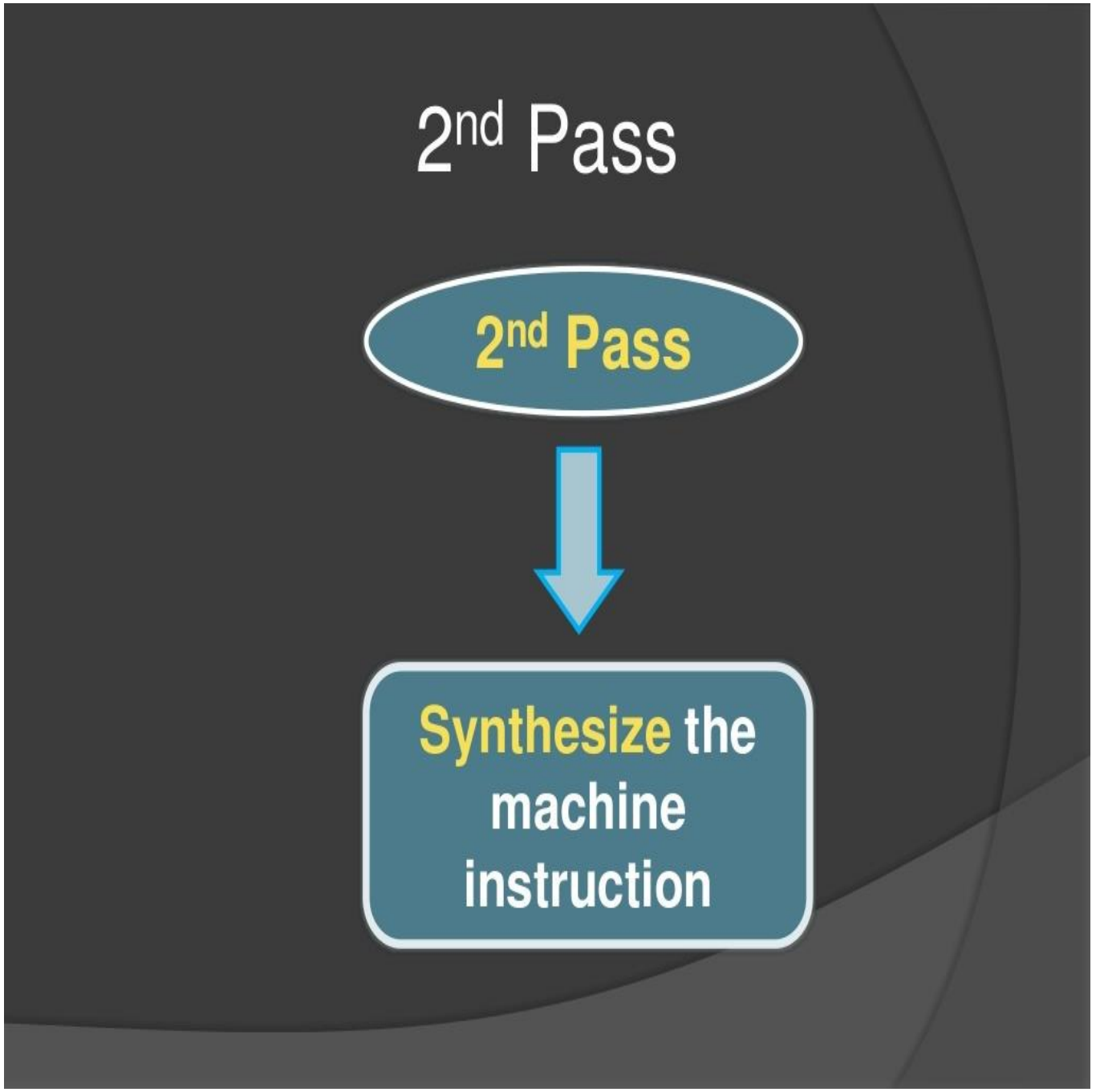



Two pass assembler
1st Pass
Performs analysis
2nd Pass
Performs synthesis

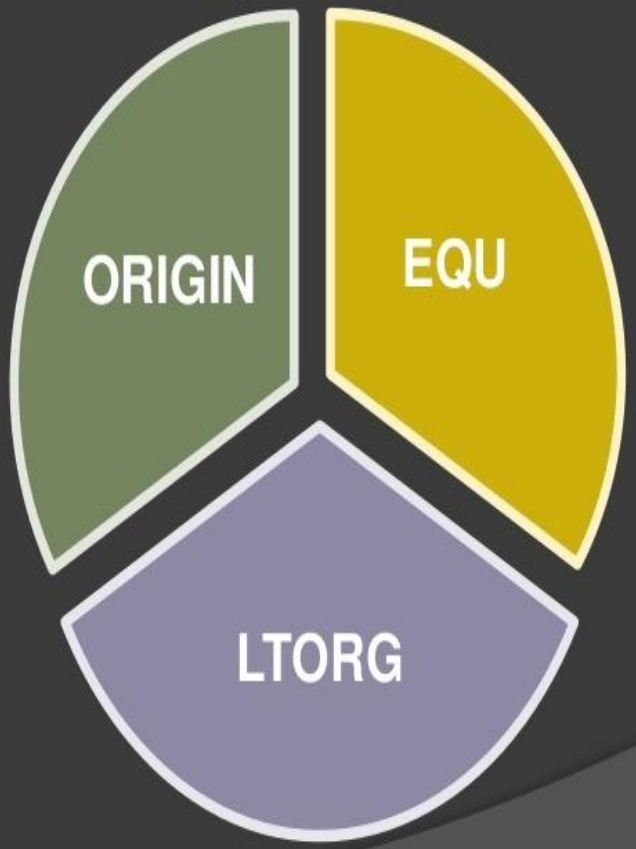

1st Pass
Constructs
1.
Data
structures
(symbol
table)
Intermediate
Code
2.
Intermediate
form of
source prog


Data Structures
Source Program
Pass 1
Pass 2
Target Program
Intermediate Code


Design of a two pass assembler
1. Separate label, opcode & operand
2. Build the symbol table
1st pass
3. Perform LC processing
4. Construct IC

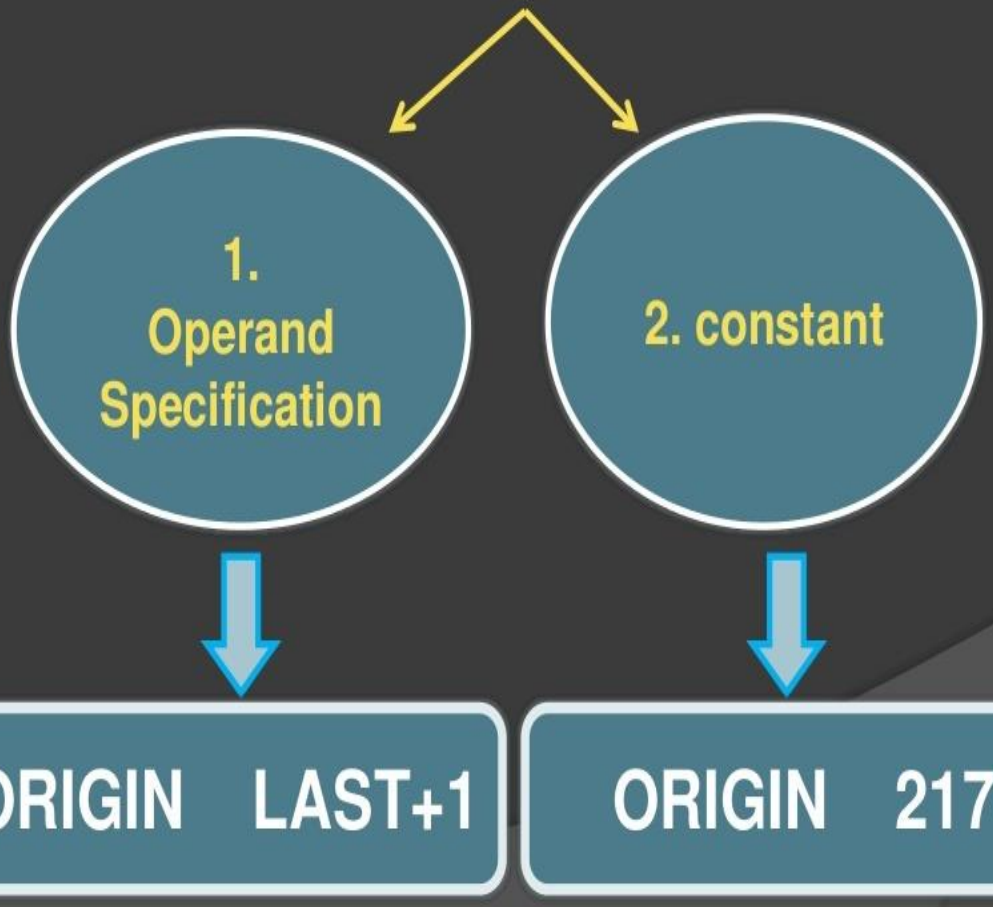

2nd Pass
2nd Pass
Synthesize the machine instruction

Advanced Assembler Directives



ORIGIN

- ORIGIN < Address Specification >



- **ORIGIN :The *origin directive* tells the assembler where to load instructions and data into memory.**
  - Syntax : ORIGIN < address spec> < address spec>
- can be an or constant Indicates that Location counter should be set to the address given by < address spec>
- This statement is useful when the target program does not consist of consecutive memory words.
  - Eg. ORIGIN Loop + 2

ORG

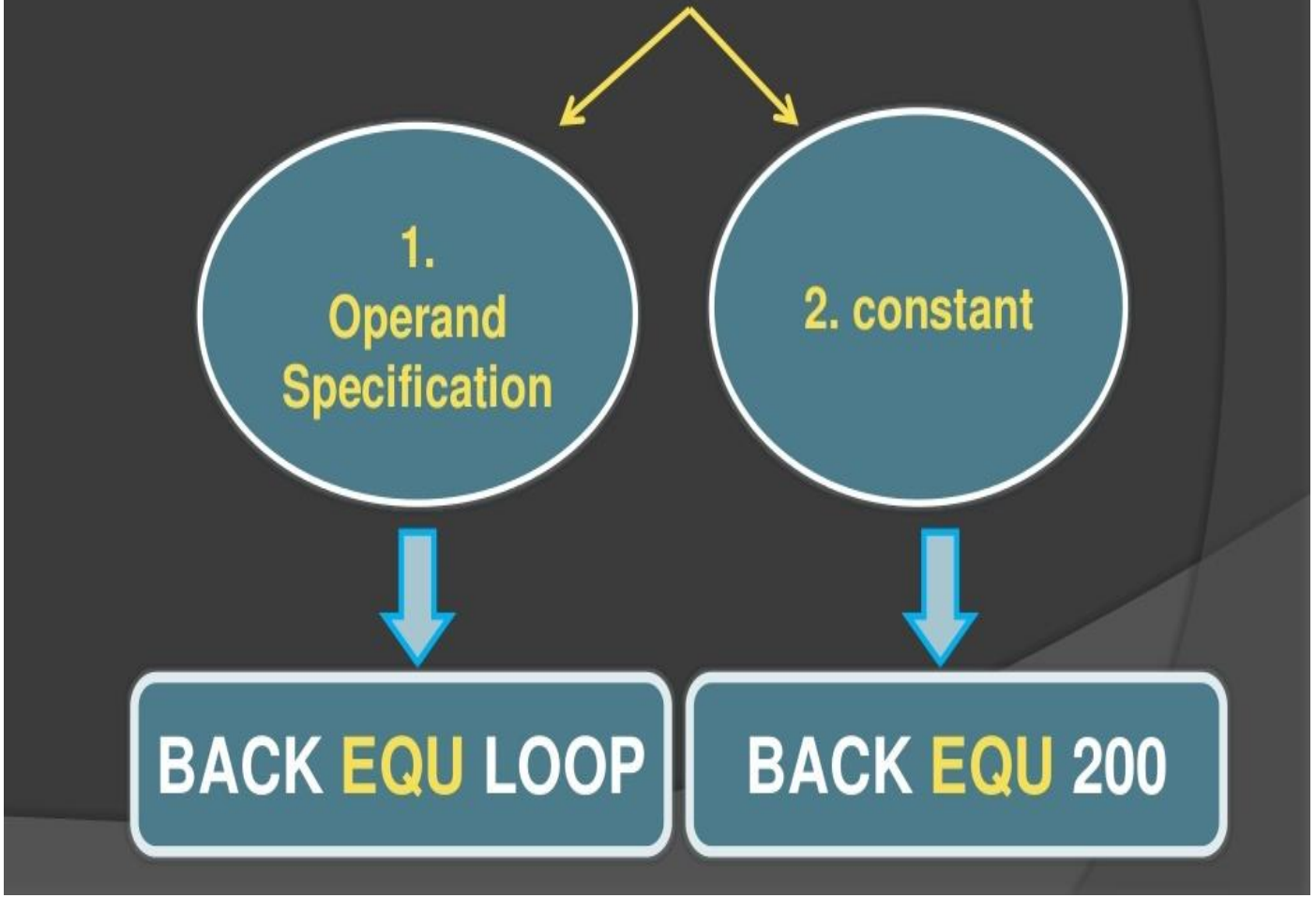
- The ORG instruction alters the setting of the location counter and thus controls the structure of the current control section.
- **The *origin directive* tells the assembler where to load instructions and data into memory.**
- It changes the program counter to the value specified by the expression in the operand field.
- Subsequent statements are assembled into memory locations starting with the new program/location counter value.
- If no ORG directive is encountered in a source program, the program counter is initialized to zero.
- Assembler uses an internal variable called LC (Location Counter) to store current offset address of the statement being processed.
- When it encounters a variable declaration statement, it puts the value of LC in its symbol table as variable's address.

Cont…

- It is useful when your target program does not consist of **consecutive** memory words.
- Operand Specification – Ability to perform **Relative LC Processing**, not absolute.
- Difference between using both the options

EQU

- Defines the symbol to represent <add spec>
- **Symbol EQU < address specification >**

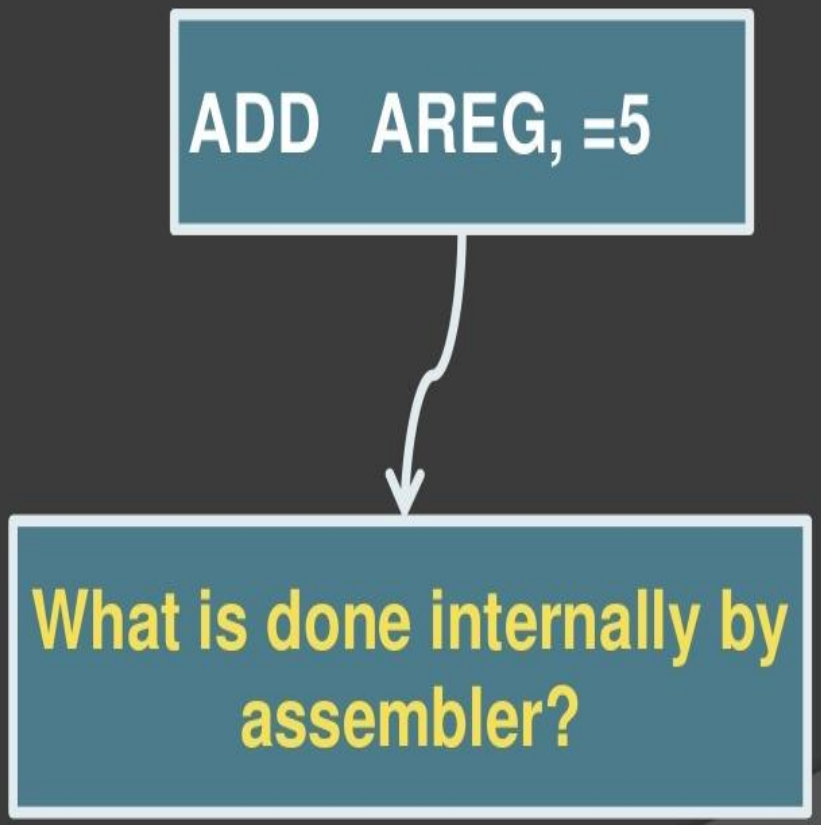


- **EQU :** It is used for making program more readable. Whenever symbol define with EQU statement no memory would be allocated only an entry would make in symbol table.
- This EQU directive is used to give a name to some value or to a symbol. Each time the assembler finds the name in the program, it will replace the name with the value or symbol you given to that name

  - Syntax EQU *operand spec (or)*

- *Simply associates the name symbol with address specification*
- *No Location counter processing is implied*
- *Back EQU Loop*
- e.g
  - FACTOR EQU 03H
  - ADD AL, FACTOR =~ ADD AL, 03H
  - A EQU 100 :
  - A is assigned to address spec 100.

Literal, why LTORG?



LTORG : (Literal Origin)

- Where should the assembler place literals ?
  - It should be placed such that the control never reaches it during the execution of a program.
  - By default, the assembler places the literals after the END statement.
  - LTROG statement permits a programmer to specify where literals should be placed.

Assembler directive

- It instructs the assembler to perform certain task during the assembly of a program

1. START
2. END
3. LTORG
4. ORIGIN
5. EQU

1. START

START <constant>

-may or may not have label

-it indicates first word of the target program

e.g. START

MOVEM AREG,A

as START has no arguments so LC =0

START 200

MOVEM AREG,A LC = 200

```
START   200
MOVER AREG,A        200
MOVEM BREG,=‘2’     201
ADD AREG,=‘2’       202
```

```
START
MOVER AREG,A        0
MOVEM BREG,=‘2’     1
ADD AREG,=‘2’       2
```

```
START   500
MOVER AREG,A
MOVEM BREG,=‘2’
ADD AREG,=‘2’
```

Contd…

2.END

-it indicates end of the program

- It also allocates addresses to literals

3.LTORG

-allocates addresses to literals

Literal Pool

-it is set of literals appearing in between

START –END

START-LTORG-END

START-LTORG –LTORG –END

Contd…

- START
  :
  :
  END

  LP=1

START
:
LTORG

LP=1

:
END

LP=2

START
:
LTORG

LP=1

:
LTORG

LP=2

:
END

LP=3

LP=literal pool

No. of literal pools= no.of LTORG statements +1

Contd…

4.ORIGIN

Syntax is:

ORIGIN <address spec>

-it indicates that LC should be set to the address given by <address specifier>

-it is useful when the target program does not consist of consecutive memory words

-programmer can specify new value of LC in terms of any symbol name or using integer constant

e.g. ORIGIN LOOP1 → symbol name with some address say 400

so during processing, assembler sets value of LC=400

ORIGIN LOOP1+4 LC= 404

ORIGIN 300 LC=300

```
START   200
MOVER AREG,A        200
MOVEM BREG,='2'     201
ADD AREG,='2'       202
ORIGIN  LOOP1
MOVER CREG, D
```

LOOP1 has address 500

```
START   200
MOVER AREG,A        200
MOVEM BREG,='2'     201
ADD AREG,='2'       202
ORIGIN  LOOP1+10
MOVER CREG, D
```

```
START   200
MOVER AREG,A        200
MOVEM BREG,='2'     201
ADD AREG,='2'       202
ORIGIN  700
MOVER CREG, D
```

Contd…

5.EQU

syntax is:

<symbol> EQU <address specifier>

<address specifier> is an <operand specifier> or <constant>

- It defines the symbol to represent <address specifier>
- This differs from the DC/DS stmt as no LC processing is implied
- Thus EQU simply associates the name <symbol> with <addr.spec>

e.g. ONE EQU LOOP1

here address specified by LOOP1 is associated with ONE

for EQU LC processing is not required i.e. value of LC is not updated

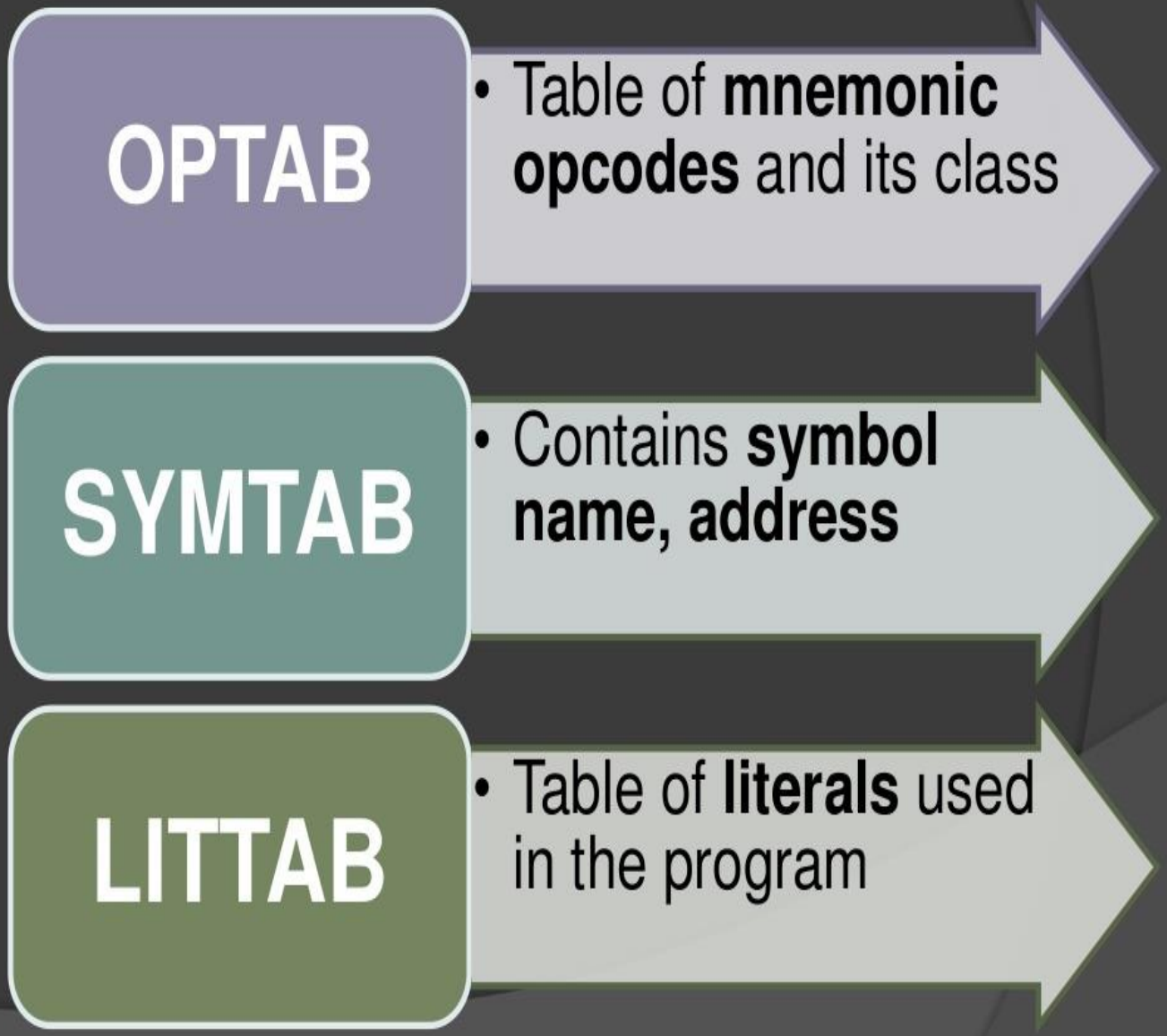
LITTAB		
Literal no.	Literal	Address
1	=‘2’	204
2	=‘3’	205
3	=‘4’	209
4	=‘2’	210

```
MOVER AREG,A      □   200
MOVEM BREG,=‘2’   □   201
ADD AREG,=‘2’     □   202
SUB BREG,=‘3’     □   203
LTORG             □   204 (  for = ‘2’  )
                  □   205 (  for = ‘3’ )
MOVER AREG,=‘4 ’  □   206
ADD BREG,=‘2’     □   207
 A   DC   5       □   208
 END              □   209   ( for =‘4 ‘ )
                  □   210   (  for =‘2’ )
```

POOLTAB[1]=1

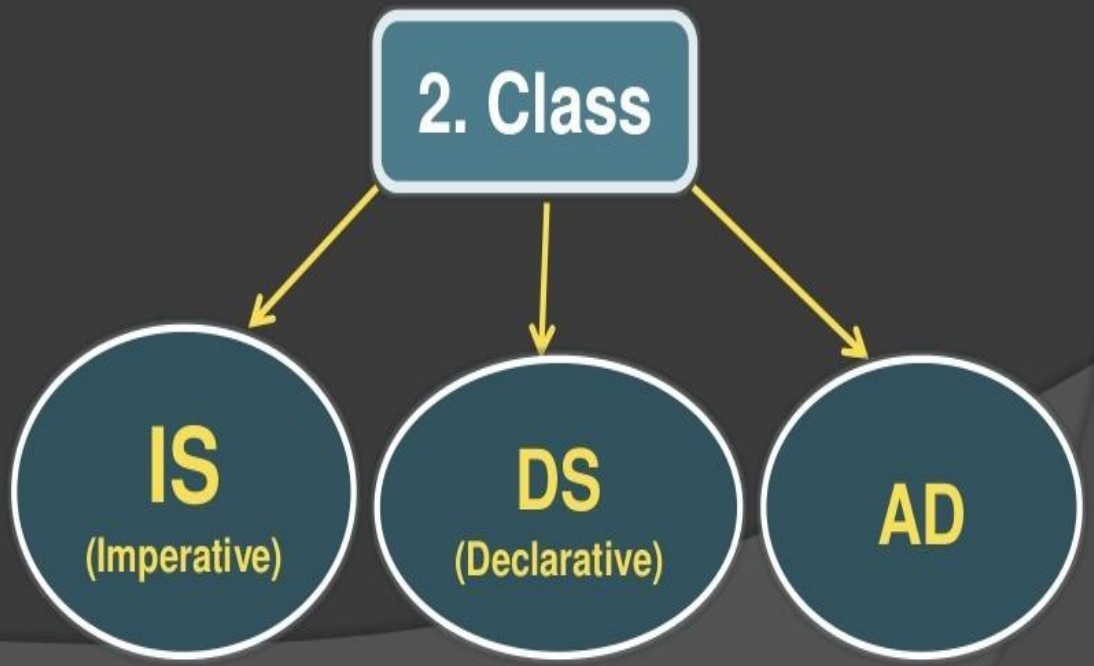
POOLTAB[2]=3

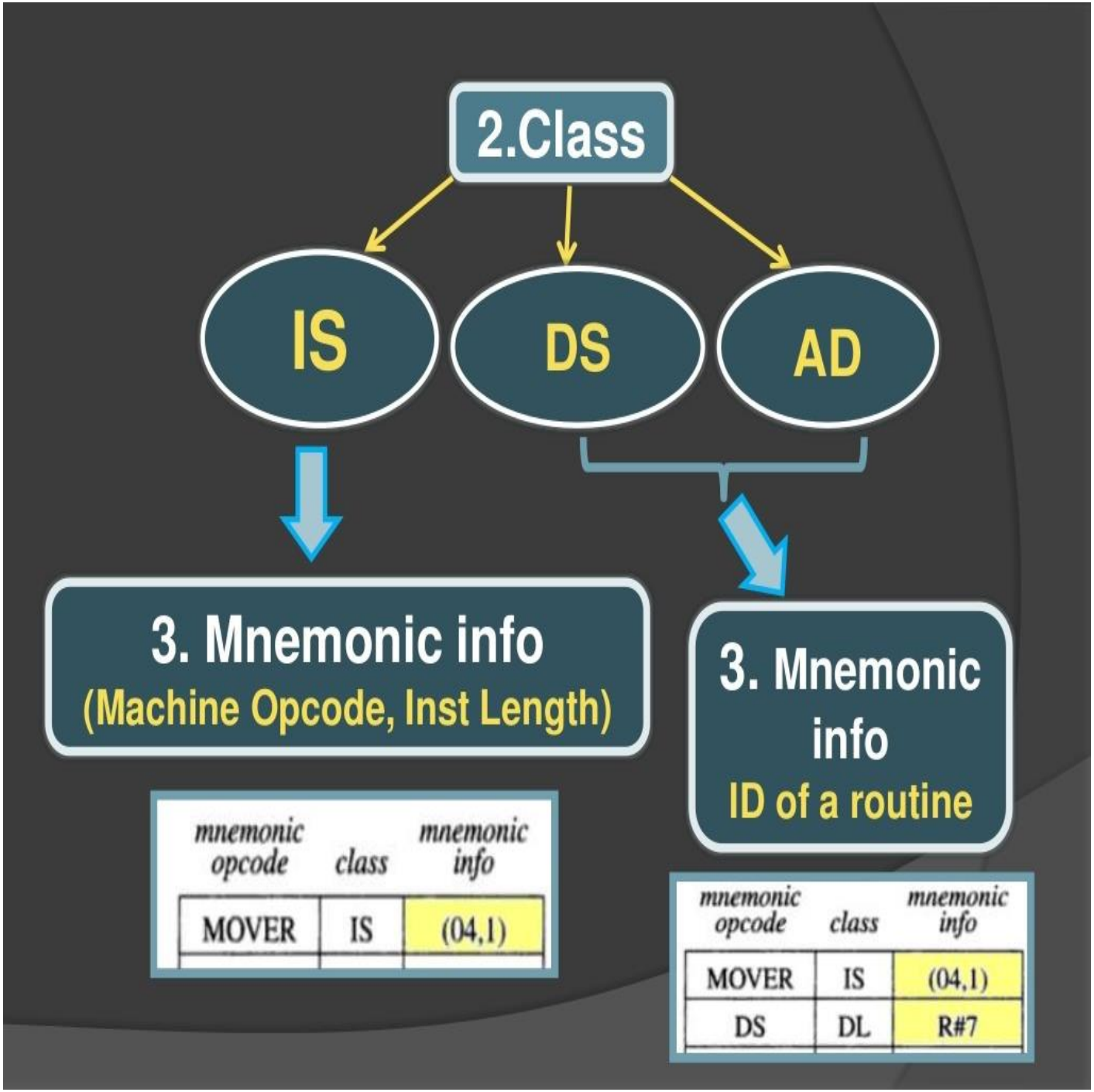
Pass -1 of the Assembler



OPTAB

- Contains
  1. mnemonic opcode
  2. class
  3. mnemonic information




2.Class
IS
DS
AD
3. Mnemonic info
(Machine Opcode, Inst Length)
3. Mnemonic info
ID of a routine
mnemonic opcode
class
mnemonic info
MOVER
IS
(04,1)
mnemonic opcode
class
mnemonic info
MOVER
IS
(04,1)
DS
DL
R#7

Opcode format

- (Statement Class, Code)

Instruction opcode	*Assembly mnemonic*
00	STOP
01	ADD
02	SUB
03	MULT
04	MOVER
05	MOVEM
06	COMP
07	BC
08	DIV
09	READ
10	PRINT

Assembler directives

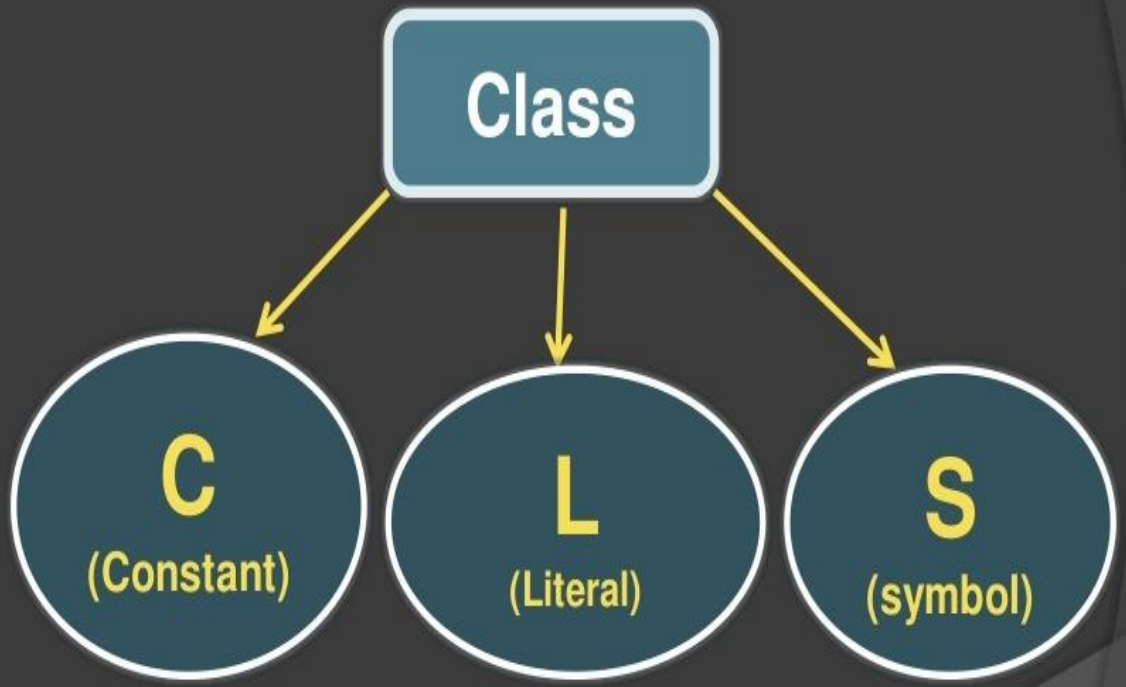
START	01
END	02
ORIGIN	03
EQU	04
LTORG	05

Declaration statements

DC	01
DS	02

Operand Specification

- (Operand Class, Code)



Features of Assembler

Assembler Design

- Machine Dependent Assembler Features
  - instruction formats and addressing modes
  - program relocation
- Machine Independent Assembler Features
  - literals
  - symbol-defining statements
  - expressions
  - program blocks
  - control sections and program linking
- Assembler design Options
  - one-pass assemblers
  - multi-pass assemblers

OPTAB

Instruction (Mnemonic/ Declaration/ Assembler Directive)	Statement Class	Machine Code
STOP	IS	00
ADD	IS	01
SUB	IS	02
MULT	IS	03
MOVER	IS	04
MOVEM	IS	05
COMP	IS	06
BC	IS	07
DIV	IS	08
READ	IS	09
PRINT	IS	10
DC	DL	01
DS	DL	02
START	AD	01
END	AD	02
ORIGIN	AD	03
EQU	AD	04
LTORG	AD	05

Register Table

Reg name	M/c Code
AREG	1
BREG	2
CREG	3
DREG	4

Condition Code for BC Instr

Condition	M/c Code
LT	1
LE	2
EQ	3
GT	4
GE	5
ANY(NE)	6

Stmt No	Example ALP
1	START 200
2	MOVER AREG, =‘5’
3	MOVEM AREG, A
4	LOOP MOVER AREG, A
5	MOVER CREG, B
6	ADD CREG, =‘1’
7	BC ANY, NEXT
8	LTORG
9	NEXT SUB AREG, =‘1’
10	BC LT, BACK
11	LAST STOP
12	ORIGIN LOOP+2
13	MULT CREG, B
14	ORIGIN LAST+1
15	A DS 1
16	BACK EQU LOOP
17	B DC 1
18	END

Stmt No	ALP	Intermediate Code			
1	START 200		AD,01		C,200
2	MOVER AREG, ='5'	200	IS,04	1	L,1
3	MOVEM AREG, A	201	IS,05	1	S,1
4	LOOP MOVER AREG, A	202	IS,04	1	S,1
5	MOVER CREG, B	203	IS,04	3	S,3
6	ADD CREG, ='1'	204	IS,01	3	L,2
7	BC ANY, NEXT	205	IS,07	6	S,4
8	LTORG	206	AD,05	-	005
		207	AD,05	-	001
9	NEXT SUB AREG, ='1'	208	IS,02	1	L,3
10	BC LT, BACK	209	IS,07	1	S,5
11	LAST STOP	210	IS,00	-	-
12	ORIGIN LOOP+2		AD,03	-	(S,2)+2
13	MULT CREG, B	204	IS,03	3	S,3
14	ORIGIN LAST+1		AD,03	-	(S,6)+1
15	A DS 1	211	DL,02	-	C,1
16	BACK EQU LOOP		AD,04	-	S,2
17	B DC 1	212	DL,01		C,1
18	END	213	AD,02	-	001

Stmt No	ALP	Intermediate Code				Machine Code			
1	START 200		AD,01		C,200				
2	MOVER AREG, ='5'	200	IS,04	1	L,1	200	04	1	206
3	MOVEM AREG, A	201	IS,05	1	S,1	201	05	1	211
4	LOOP MOVER AREG, A	202	IS,04	1	S,1	202	04	1	211
5	MOVER CREG, B	203	IS,04	3	S,3	203	05	03	212
6	ADD CREG, ='1'	204	IS,01	3	L,2	204	01	03	207
7	BC ANY, NEXT	205	IS,07	6	S,4	205	07	6	208
8	LTORG	206	AD,05	-	005	206	00	0	005
		207	AD,05	-	001	207	00	0	001
9	NEXT SUB AREG, ='1'	208	IS,02	1	L,3	208	02	1	213
10	BC LT, BACK	209	IS,07	1	S,5	209	07	1	202
11	LAST STOP	210	IS,00	-	-	210	00	0	000
12	ORIGIN LOOP+2		AD,03	-	(S,2)+2				
13	MULT CREG, B	204	IS,03	3	S,3	204	03	3	212
14	ORIGIN LAST+1		AD,03	-	(S,6)+1				
15	A DS 1	211	DL,02	-	C,1	211			
16	BACK EQU LOOP		AD,04	-	S,2				
17	B DC 1	212	DL,01		C,1	212			
18	END	213	AD,02	-	001	213	00	0	001

Data Structures Generated after Pass I

SYMTAB			
Sym_id	Sym_name	Sym_addr	length
1	A	211	1
2	LOOP	202	1
3	B	212	1
4	NEXT	208	1
5	BACK	202	1
6	LAST	210	1

LITTAB		
Lit_no	Literal	addr
1	=‘5’	206
2	=‘1’	207
3	=‘1’	213

POOLTTAB
POOLTAB[1]=1
POOLTAB[2]=3

ALP with Data structures Generated

	START 200	
	MOVER AREG,='5'	200
	MOVEM AREG,A	201
LOOP	MOVER AREG,A	202
	MOVER CREG, B	203
	ADD CREG,='1'	204
	LTORG	205 206
NEXT1	SUB AREG,='1'	207
	ORIGIN LOOP+8	
	MUL CREG,B	210
A	DS 2	211
B	DC 3	213
NEXT2	EQU LOOP	
	END	214

	SYMBOL TABLE		
Sym_id	Sym_name	Sym_addr	length
1	A	211	2
2	LOOP	202	1
3	B	213	1
4	NEXT1	207	1
5	NEXT2	202	1

LITERAL TABLE			
Lit_no		Literal	addr
LP1	1	5	205
	2	1	206
LP 2	3	1	214

POOL TABLE
POOLTAB[1] = 1
POOLTAB[2] = 3

Algorithm for Pass 1 of 2 pass Assembler

Step 1: loc_cntr : = 0; pooltab_ptr := 1; POOLTAB[1] :=1;
Littab_ptr :=1; symtab_ptr:=1;

Step 2: While next stmt is not an END stmt

(a) If label is present then .....

(b) If an LTORG stmt then .....

(c) If START or ORIGIN stmt then .....

(d) If an EQU stmt then …….

(e) If a declaration stmt then …….

(f) If an imperative stmt then …….

Step 3: Processing of END stmt

(a) Perform step 2(b)

(b) Generate Intermediate code.

(C) Goto Pass 2 .

Label Processing

(a) If label is present then

this_label = symbol in label field

Enter(this_label, loc_cntr) in SYMTAB

Literal Processing

(b) If an LTORG stmt then

i. Process literals
LITTAB[POOLTAB[pooltab_ptr]]……
LITTAB[POOLTAB[pooltab_ptr+1]]-1]

to allocate memory and put the address field.

Update loc_cntr.

ii. Pooltab_ptr:=pooltab_ptr+1;

iii. POOLTAB[pooltab_ptr] := littab_ptr;

START ORIGIN and EQU Processing

(c) If START or ORIGIN stmt then

loc_cntr := value in operand field

(d) If an EQU stmt then

this_addr=value of <address spec>

update the SYMTAB entry

Declaration(DS/DC) Statement Processing

(e) If a declaration stmt then

code = code of declaration stmt,

size = size req by DC/DS

update the SYMTAB entry

loc_cntr = loc_cntr + size

generate Intermediate code

Imperative Statement Processing

(f) If an imperative stmt then

code = m/c code from MOT,

loc_cntr = loc_cntr + length of instr

If operand is literal then

this_lit = literal in operand field

LITTAB[littab_ptr] = this_lit

littab_ptr = littab_ptr + 1

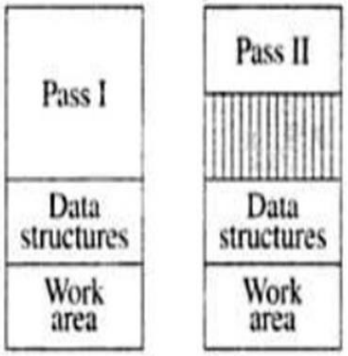
else this_entry = SYMTAB entry no of operand

symtab_ptr = symtab_ptr + 1

- **Pass-1:**
  - Define symbols and literals and remember them in symbol table and literal table respectively.
  - Keep track of location counter
  - Process pseudo-operations
- **Pass-2:**
  - Generate object code by converting symbolic op-code into respective numeric op-code
  - Generate data for literals and look for values of symbols

Variants of IC

	START	200	(AD,01)	(C,200)
	READ	A	(IS,09)	(S,01)
LOOP	MOVER	AREG, A	(IS,04)	(1)(S,01)
	⋮		⋮	
	SUB	AREG, ='1'	(IS,02)	(1)(L,01)
	BC	GT, LOOP	(IS,07)	(4)(S,02)
	STOP		(IS,00)	
A	DS	1	(DL, 02)	(C,1)
	LTORG		(DL,05)	
	...		...	



(a)

There are two variant of Intermediate code

Variant-1

1) We may have IS, AD , DL in our program so we have to write (class, its number)

2) Operand registers are written with single digit.

3) The second operand which is a memory operand, is represented by a pair of the form (operand class, code) Where operand class is one of C, S and L standing for constant, symbol and literal respectively.

4) The first operands may be register value for instruction. If the instruction is BC then first operand is having value 1 to 6 .

Variant-02

1) Variant 2 will be same for AD and DL. Only for IS the first operand is written as it is. For second operand only for literal they follow VARIANT format, rest all is written as it is from input.

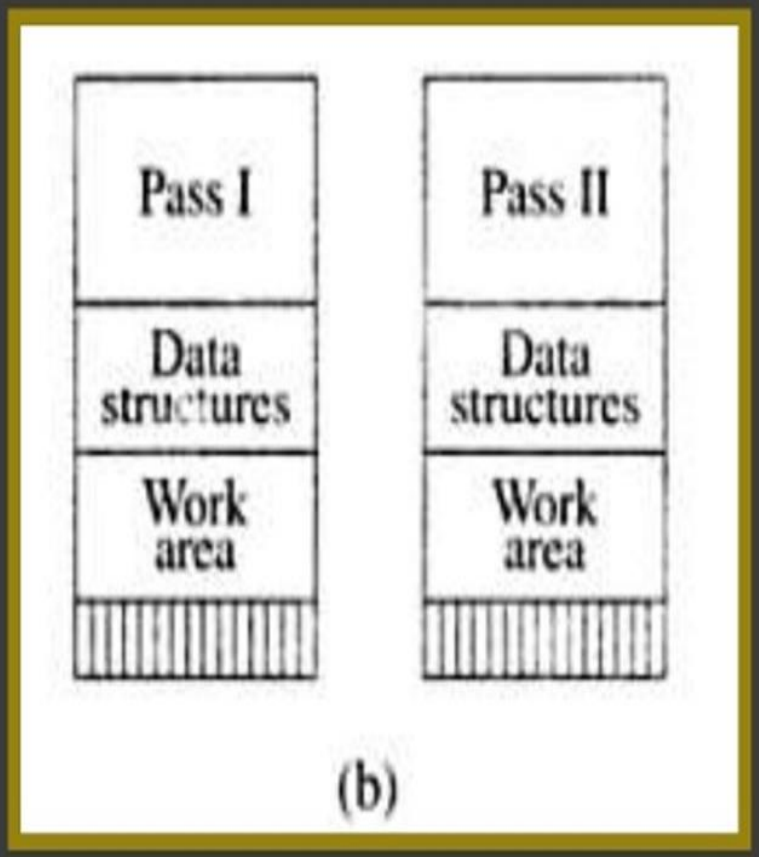
Intermediate code in variant I & variant II

Assembly Program			Variant I		Variant II	
	START	200	(AD,01)	(C, 200)	(AD,01)	(C, 200)
	READ	A	(IS, 09)	(S, 01)	(IS, 09)	A
LOOP	MOVER	AREG, A	(IS, 04)	(1)(S, 01)	(IS, 04)	AREG, A
	.		.		.	
	.		.		.	
	SUB	AREG, ='1'	(IS, 02)	(1)(L, 01)	(IS, 02)	AREG,(L, 01)
	BC	GT, LOOP	(IS, 07)	(4)(S, 02)	(IS, 07)	GT, LOOP
	STOP		(IS, 00)		(IS, 00)	
A	DS	1	(DL, 02)	(C,1)	(DL, 02)	(C,1)
	LTORG		(AD, 05)		(AD, 05)	
	.....					

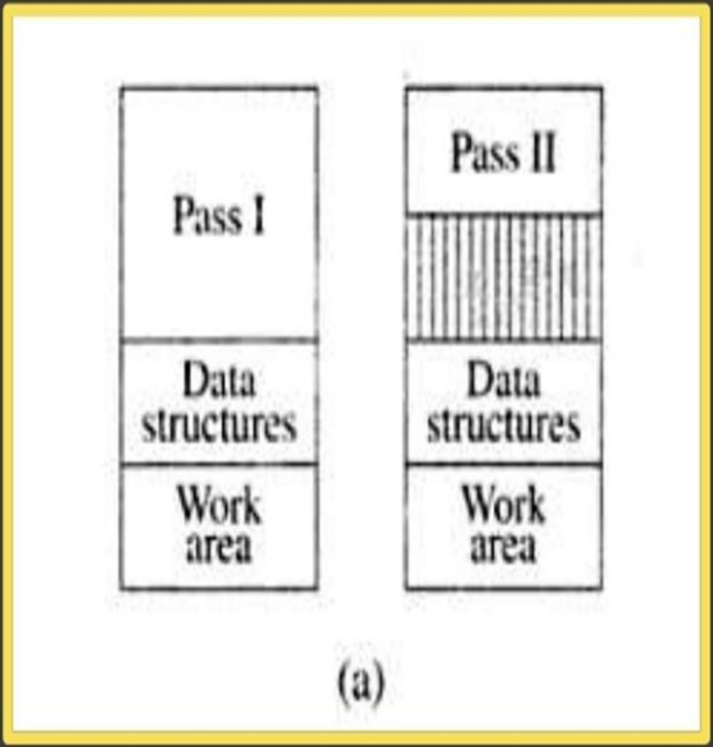
Variant - 2 of IC

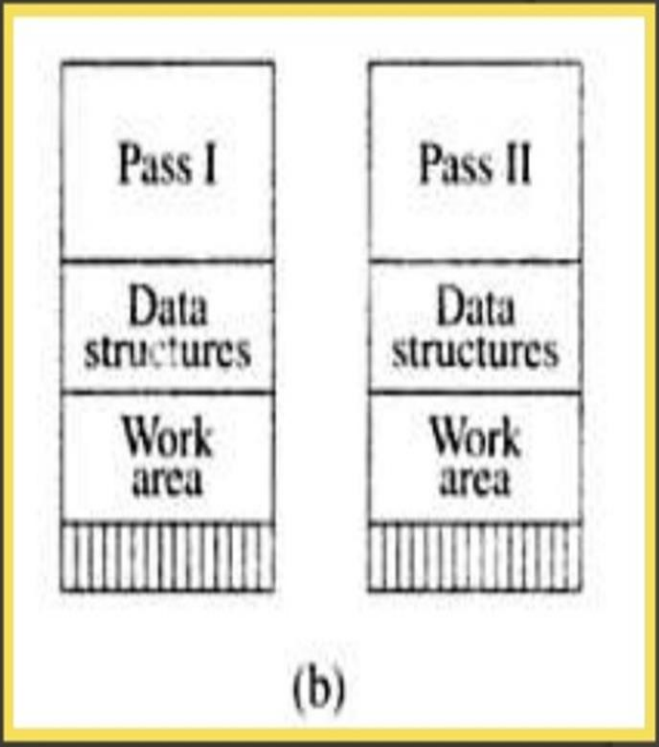
	START	200	(AD,01)	(C,200)
	READ	A	(IS,09)	A
LOOP	MOVER	AREG, A	(IS,04)	AREG, A
	⋮		⋮	
	SUB	AREG, ='1'	(IS,02)	AREG, (L,01)
	BC	GT, LOOP	(IS,07)	GT, LOOP
	STOP		(IS,00)	
A	DS	1	(DL,02)	(C,1)
	LTORG		(DL,05)	
	...		...	

Variant-2 of IC



Variants of IC





- ✓Extra work in Pass I
- ✓Simplified Pass II
- ✓Pass I code occupies more memory than code of Pass II
- ✓Does not simplify the task of Pass II or save much memory in some situation.

- ✓IC is less compact
- ✓Memory required for two passes would be better balanced
- ✓So better memory utilization

Algorithm for Pass 2 of 2 pass Assembler

Machine_code_buffer :area for constructing code for one statement

Code_area: area for assembling the target program ,

code_area_address :contains address of code_area

1. **code_area_addr=addr of code_area,**
   pooltab_ptr=1,
   loc_cntr=0

Algorithm for Pass 2 of 2 pass Assembler (contd…)

2. While next stmt is not an END stmt

(a) clear machine_code_buffer

(b) If an LTORG stmt

(i) Process literals in LITTAB[POOLTAB[pooltab_ptr]]……..LITTAB[POOLTAB[pooltab_ptr+1]-1] assemble literals in machine_code_buffer.

(ii) size=size of memory req for literals (iii)pooltab_ptr=pooltab_ptr+1

(c) If a START or ORIGIN stmt then

(i) loc_cntr=value specified in operand field (ii) size=0

(d) If a declaration stmt

(i) If a DC stmt then

Assemble the const in machine_code_buffer.

(ii) size=size of memory required by DC/DS stmt

(e) If an imperative stmt

(i) Get operand address from SYMTAB or LITTAB

(ii) Assemble instr in machine_code_buffer. (iii) size=size of instr

(f) If size <> 0 then

(i) Move contents of machine_code_buffer to the address code_area_addr+loc_cntr

(ii) loc_cntr=loc_cntr+size

3.Processing of END stmt

(a) Perform step 2(b) and 2(f)

(b) Write code_area into output file.

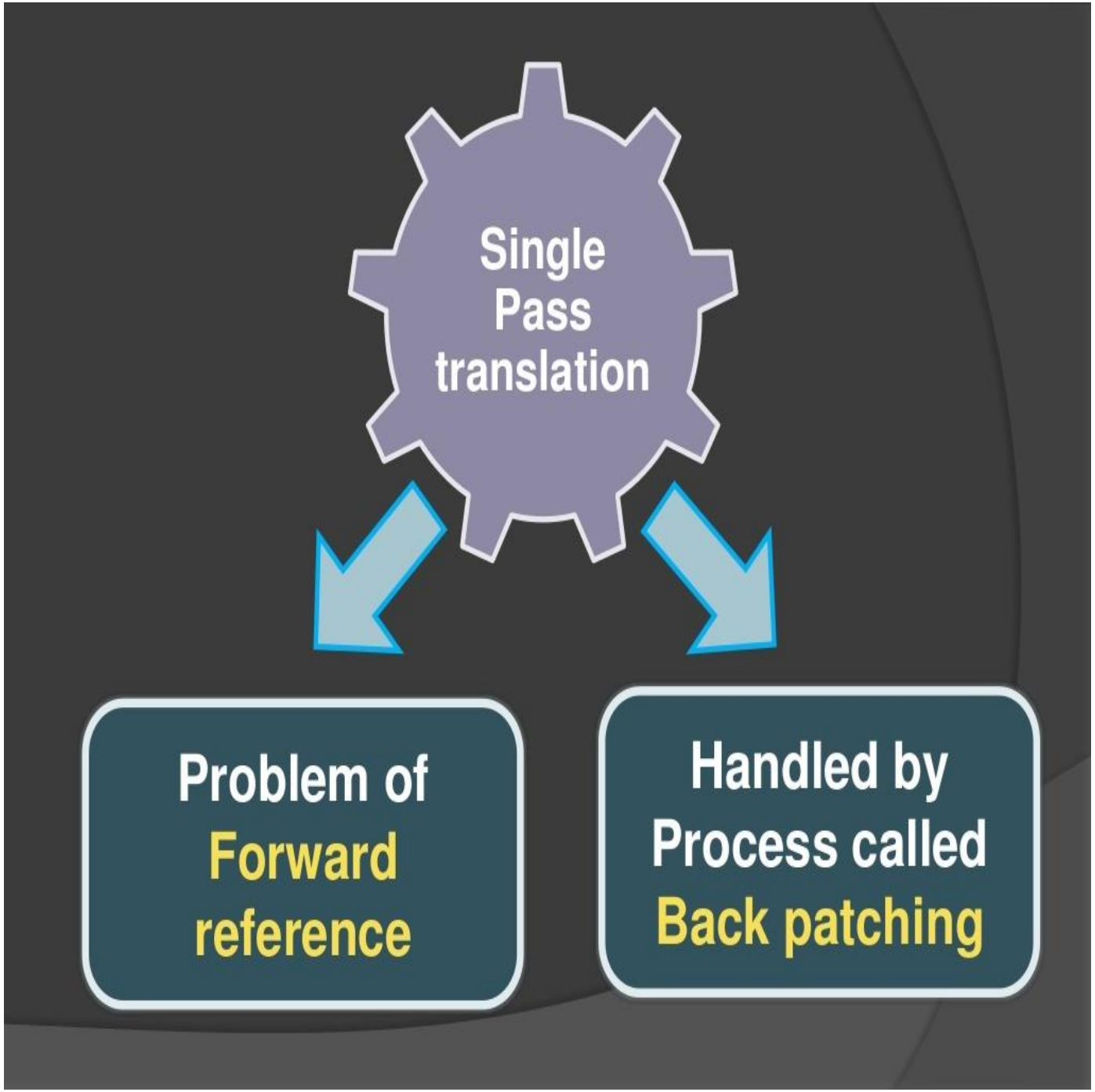
Listing and error reporting in Pass-1

- Syntax errors(missing commas or parenthesis)
- Semantic errors (duplicate definitions of symbols)
- References to undefined variables

Sr. No	Stmt	address
001	START 200	
002	MOVER AREG,A	200
003	….	
009	MVER BREG,A	207
	**ERROR ** INVALID OPCODE	
010	ADD BREG,B	208
014	A DS 1	209
015	…….	
021	A DC ‘5’	227
	** ERROR ** DUPLICATE DEFINITION OF SYM A	
022	……	
035	END	

ERRORS IN PASS 2

Sr. No	Stmt	address
001	START 200	
002	MOVER AREG,A	200
003	….	
009	MVER BREG,A	207
	**ERROR ** INVALID OPCODE	
10	ADD BREG,B	208
	** ERROR ** UNDEFINED SYM B IN OPERAND FIELD	
014	A DS 1	209
015	…….	
021	A DC ‘5’	227
	** ERROR ** DUPLICATE DEFINITION OF SYM A	
022	……	
035	END	


Single
Pass
translation
Problem of
Forward
reference
Handled by
Process called
Back patching

Back patching

- The **operand** field of an instruction is **containing forward reference is kept blank** initially.
- The address of that symbol is put into field when its **address is encountered.**

Thank you