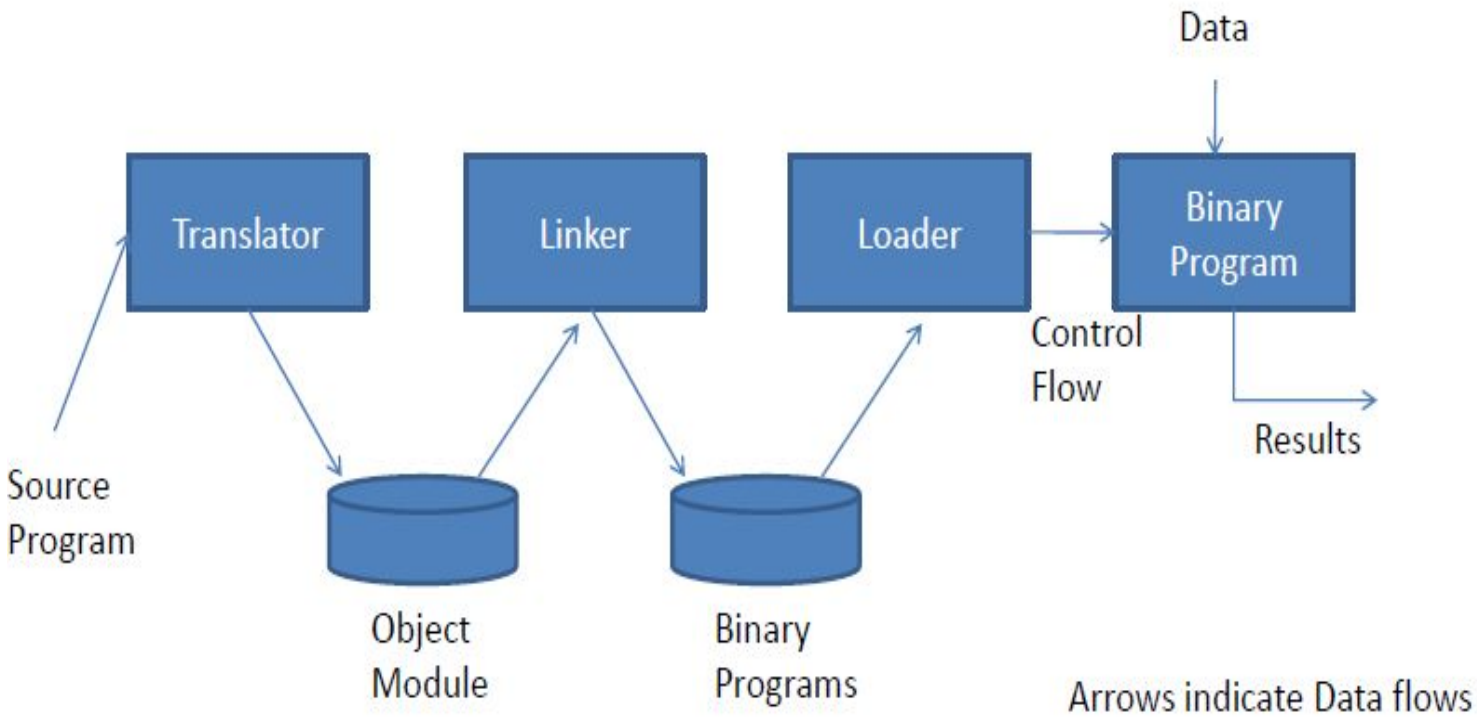
Linkers

Linker

- **Steps for Execution:**

1. **Translation** of program
2. **Linking** of program with other programs needed for its execution.
3. **Relocation** of the program to execute from the specific memory area allocated to it.
4. **Loading** of the program in the memory for the purpose of execution.


Data
Translator
Linker
Loader
Binary Program
Control Flow
Results
Source Program
Object Module
Binary Programs
Arrows indicate Data flows

Linkers

- Links with other programs needed for its execution
- Processes a set of object modules to produce a ready-to-execute program form called binary program
- Loader loads this program into memory for execution

Linker

- A Linker is a system program that combines the code of a target program with codes of other programs and library routines

Object Module and Binary Program

- Object Module:
  - Contains target code (Machine language) of the program and information about other programs and library routines that it needs to invoke during its execution
- Binary Program:
  - Target code and other program routines combined together to form Binary program

Addresses

Address of a program entity may vary at different times:

1. Translation time address: Address assigned by translator (ORIGIN or START)
2. Linked address: Address assigned by linker
3. Load time address: Address assigned by loader

Addresses

Origin of a program may have to be changed by linker or loader because

1. Same set of translated addresses may have been used in different object modules, resulting in memory conflicts
2. OS MM module may require that a program should be allocated specific area of memory

Example:

	Statement		Address	Code
	START	500		
	ENTRY	TOTAL		
	EXTRN	MAX, ALPHA		
	READ	A	500)	+ 09 0 540
LOOP			501)	
	.			
	.			
	MOVER	AREG, ALPHA	518)	+ 04 1 000
	BC	ANY, MAX	519)	+ 06 6 000
	.			
	.			
	BC	LT, LOOP	538)	+ 06 1 501
	STOP		539)	+ 00 0 000
A	DS	1	540)	
TOTAL	DS	1	541)	
	END			

The translated origin

The Translated Time Address of LOOP

Relocation concept

- Program relocation is the process of modifying the addresses used in the address sensitive instructions of a program such that the program can execute correctly from the designated area of memory
- If linked origin ≠ translated origin, relocation must be performed by the linker
- If load origin ≠ linked origin, relocation must be performed by the loader

Sample Assembly Language Program and generated code (Program P)

```
          START  500
          ENTRY  TOTAL
          EXTERN      MAX,ALPHA
          READ   A                  500 +400)      09  00   540+400=940
LOOP                                501+400)  901
          ----
          MOVER      AREG, ALPHA          518+400) 918  04   01   000
          BC         ANY, MAX             519+400) 919  07   06   000
          -----
          BC         LT, LOOP             538) 07    01  501
          STOP                  539) 00    00  000
A         DS         1          540)
TOTAL     DS         1          541)
          END
```

Performing Relocation

t_origin_p - translated origin of program P

l_origin_p - linked origin of program P

t_{symb} - translation time address of a symbol symb

l_{symb} - link time address of a symbol symb

Relocation factor of P is defined as

$$relocation\_factor_p = l\_origin_p - t\_origin \quad \text{------1}$$

Performing Relocation

$relocation\_factor_p = l\_origin_p - t\_origin$ ------1

$t_{symb} = t\_origin_p + d_{symb}$ -----2

$l_{symb} = l\_origin_p + d_{symb}$ -----3

From 1 and 3

$l_{symb} = t\_origin_p + relocation\_factor_p + d_{symb}$ -----4

From 2 and 4

$l_{symb} = t_{symb} + relocation\_factor_p$ -----5

For Program P:

- Translated origin is 500
- Suppose l_origin = 900
- Relocation_factor = 900- 500 = 400
- Relocation will be performed for instructions with translated time address 500 and 538
  - For instruction with translated time address 500: address 540 in operand field will change to (540+400) = 940
  - For instruction with translated time address 538: address 501 in operand field will change to (501+400) = 901

Linking

- Program interacts with another program unit using its instructions & data in its own instructions
- Public definitions & external references required
  - ENTRY: Public definitions
  - A symbol defined in a program unit that may be referenced in other program unit.
  - EXTRN: External references
  - A reference to a symbol that is not defined in the program unit containing the reference (defined in other program)
- Linking is the process of binding an external reference to the correct link time address

Program Q

```
        START   200
        ENTRY   ALPHA
        --
ALPHA   DS      25      231)  00  00  025
        END
```

Linkers

Object module contains all info necessary to relocate & link program with other programs

1. Header : has translated origin, size & execution start address
2. Program : has machine code
3. Relocation table (RELOCTAB) : each entry contains translated address of an address sensitive instruction
4. Linking table (LINKTAB): contains PD/EXT symbols

Linker generates the linked addresses of all the symbols & instructions

RELOCTAB and LINKTAB

- Program P:
- RELOCTAB:
  - 500) 09 00 540
  - 538) 07 01 501
- LINKTAB:
  - TOTAL PD
  - MAX EXT
  - ALPHA EXT

RELOCTAB and LINKTAB

- Program Q:
- LINKTAB:
  - ALPHA PD

NTAB:

Symbol	Linked addr
P	900
TOTAL	941
Q	942
ALPHA	973

Linking of Program P and Q

Program P:

```
        START 500
        ENTRY       TOTAL
        EXTERN      MAX,ALPHA
        READ        A                   900)  09  00   940
        LOOP                            901)
          ----
              MOVER      AREG, ALPHA              918)  04   01   973
              BC     ANY, MAX                 919)  07   06   000
          -----
        BC     LT, LOOP                 938)  07    01  901
        STOP                        939)  00    00  000
        A          DS 1                 940)
        TOTAL    DS 1                   941)
              END
```

Program Q:

```
        START       200
        ENTRY       ALPHA
        --                                          942)
        ALPHA   DS 25                   973)  00  00  025
        END
```

Self-Relocating Programs

Programs can be classified into

1. Non relocatable programs

- cannot be executed in any memory area other than its translated origin

-due to lack of information pertaining to address sensitive instructions in program

2. Relocatable programs

- Has info available related to address sensitive instructions in program

3. Self-relocating programs

Self-Relocating Programs

- Performs relocation of its own address sensitive instructions
- 2 provisions for this

1. Table containing address sensitive instructions exists as part of program
2. Relocating logic: Code to perform relocation of address sensitive instructions also exists as part of program

- Can execute in any area of memory
- Useful in time sharing operating systems

Static Link Libraries

- Is the process of copying all library modules used in the program into the final executable image.
- This is performed by the linker and it is done as the last step of the compilation process.
- The linker combines library routines with the program code in order to resolve external references, and to generate an executable image suitable for loading into memory.
- When the program is loaded, the operating system places into memory a single file that contains the executable code and data.
- This statically linked file includes both the calling program and the called program.
- Statically linked files are significantly larger in size because external programs are built into the executable files.

Static Link Libraries

- If any of the external programs change then they have to be recompiled and re-linked again else the changes won't reflect in existing executable file.
- Statically linked program takes constant load time every time it is loaded into the memory for execution
- Programs that use statically-linked libraries are usually faster
- In statically-linked programs, all code is contained in a single executable module. Therefore, they never run into compatibility issues.

Dynamic Link Libraries

- In dynamic linking the names of the external libraries (shared libraries) are placed in the final executable file while the actual linking takes place at run time when both executable file and libraries are placed in the memory.
- Several programs use a single copy of an executable module.
- Is performed at run time by the operating system
- Only one copy of shared library is kept in memory. This significantly reduces the size of executable programs, thereby saving memory and disk space
- Individual shared modules can be updated and recompiled. This is one of the greatest advantages dynamic linking offers.

Dynamic Link Libraries

- Load time might be reduced if the shared library code is already present in memory.
- Programs that use shared libraries are usually slower than those that use statically-linked libraries.
- Dynamically linked programs are dependent on having a compatible library. If a library is changed (for example, a new release may change a library), applications might have to be reworked to be made compatible with the new version of the library. If a library is removed from the system, programs using that library will no longer work.