LECTURE 3

Translation

PROCESS MEMORY

There are four general areas of memory in a process.

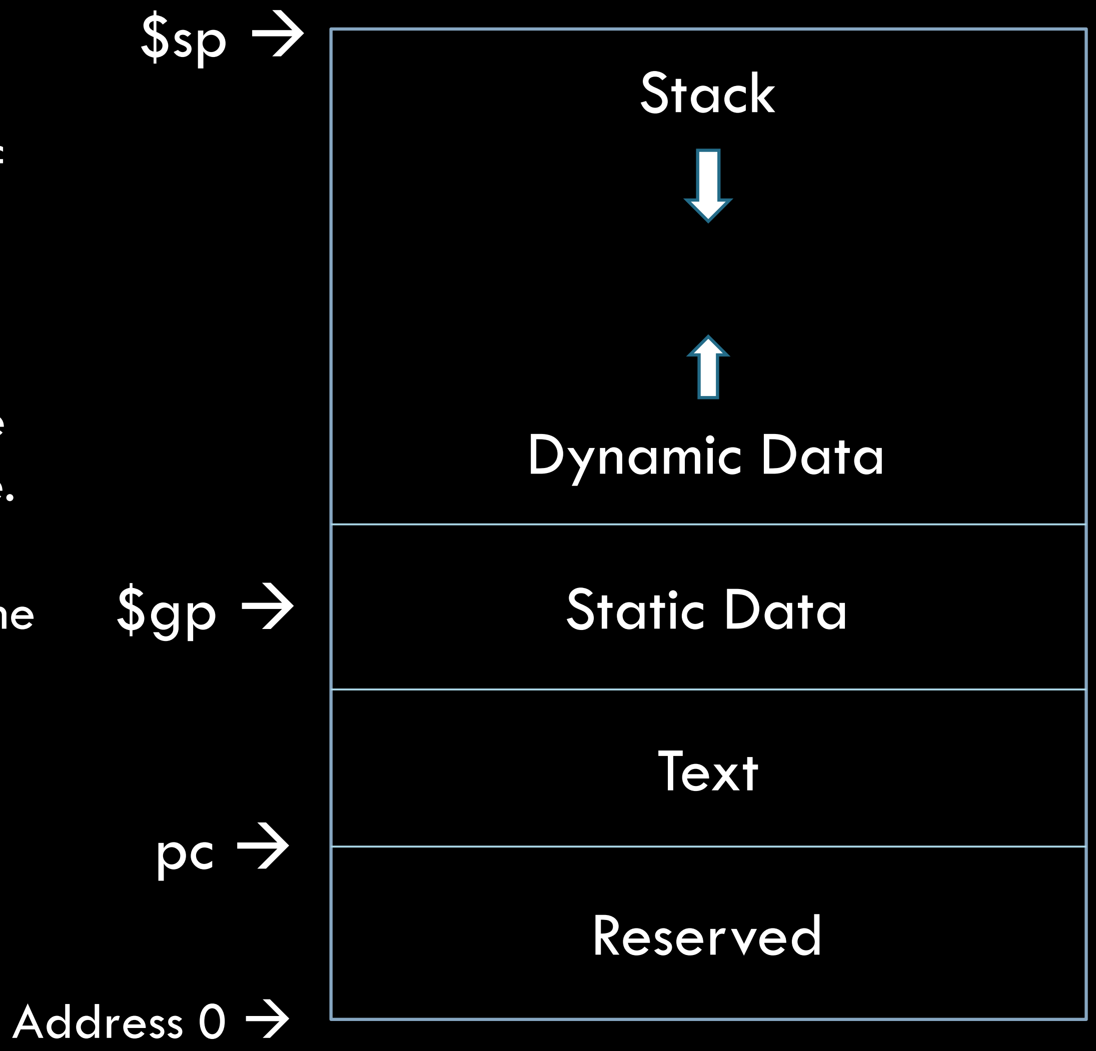
- The **text** area contains the instructions for the application and is fixed in size.
- The **static data** area is also fixed in size and contains:
  - Global variables
  - Static local variables
  - String and sometimes floating-point constants
- The **run-time stack**
  - Contains *activation records*, each containing information associated with a function invocation.
  - Saved values of callee-saved registers
  - Local variables and arguments not allocated to registers.
  - Space for the maximum words of arguments passed on stack to other functions.
- The **heap** contains dynamically allocated data (e.g. data allocated by the new operator in C++ or malloc function call in C).

ORGANIZATION OF PROCESS MEMORY

Here is MIPS convention for allocation of memory.

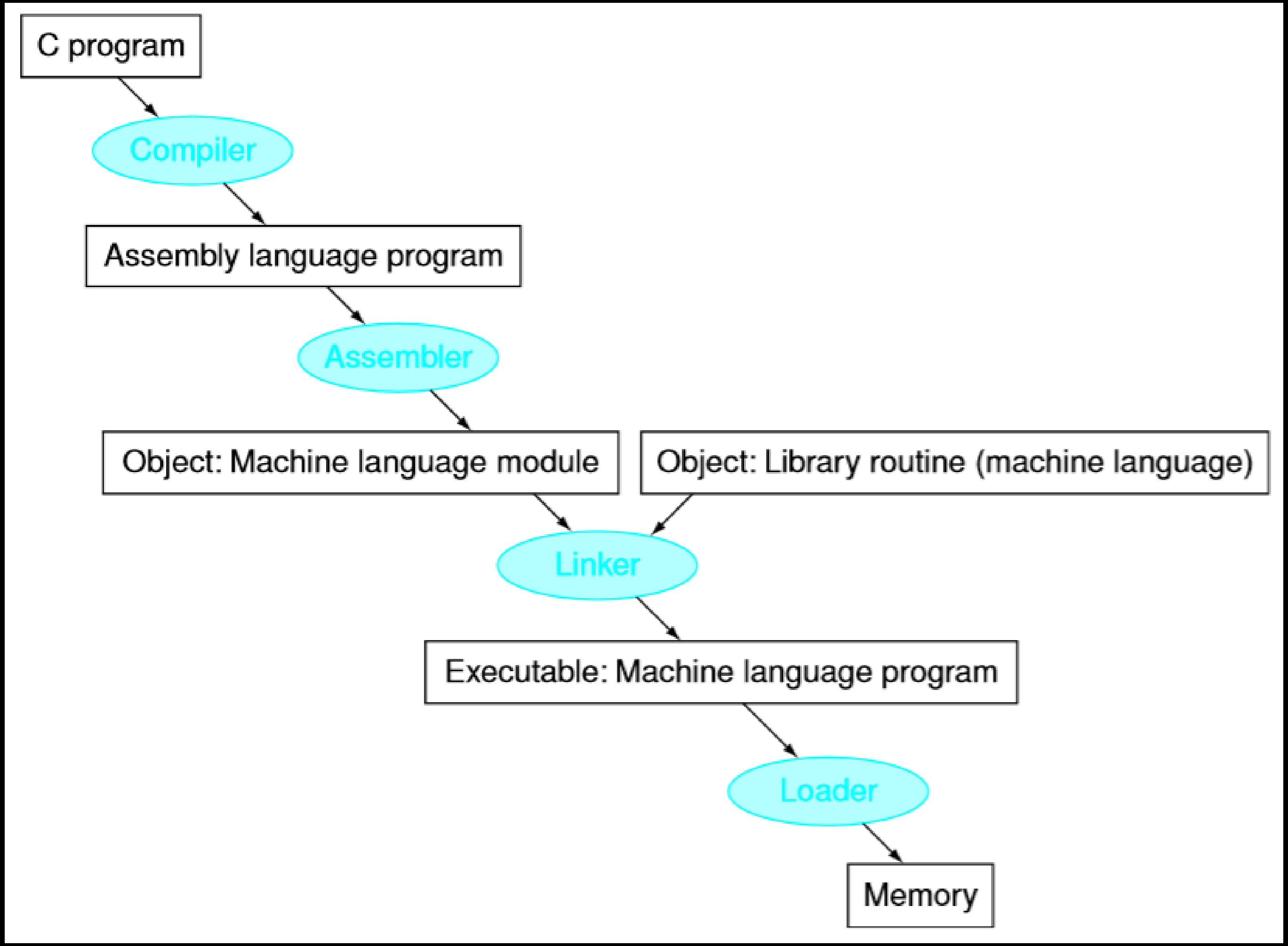
The stack starts at the higher-end of memory and grows downward, while the heap grows upward into the same space.

The lower end of memory is reserved. The text segment follows, housing the MIPS machine code.



TRANSLATION PROCESS

- Preprocessing
- Compiling
- Assembling
- Linking
- Loading


C program
Compiler
Assembly language program
Assembler
Object: Machine language module
Object: Library routine (machine language)
Linker
Executable: Machine language program
Loader
Memory

PREPROCESSING

Some preliminary processing is performed on a C or C++ file.

- Definitions and macros
- File inclusion
- Conditional compilation

Try g++ with the -E option!

COMPILING

Compiling is referred to as both the entire translation process from source file to executable or the step that translates a source file in a high-level language (sometimes already preprocessed) and produces an assembly file.

Compilers are also responsible for checking for correct syntax, making semantic checks, and performing optimizations to improve performance, code size, and energy usage.

ASSEMBLING

Assemblers take an assembly language file as input and produce an object file as output.

Assembling is typically accomplished in two passes.

- First pass: stores all of the identifiers representing addresses or values in a table as there can be forward references.
- Second pass: translates the instructions and data into bits for the object file.

THE OBJECT FILE

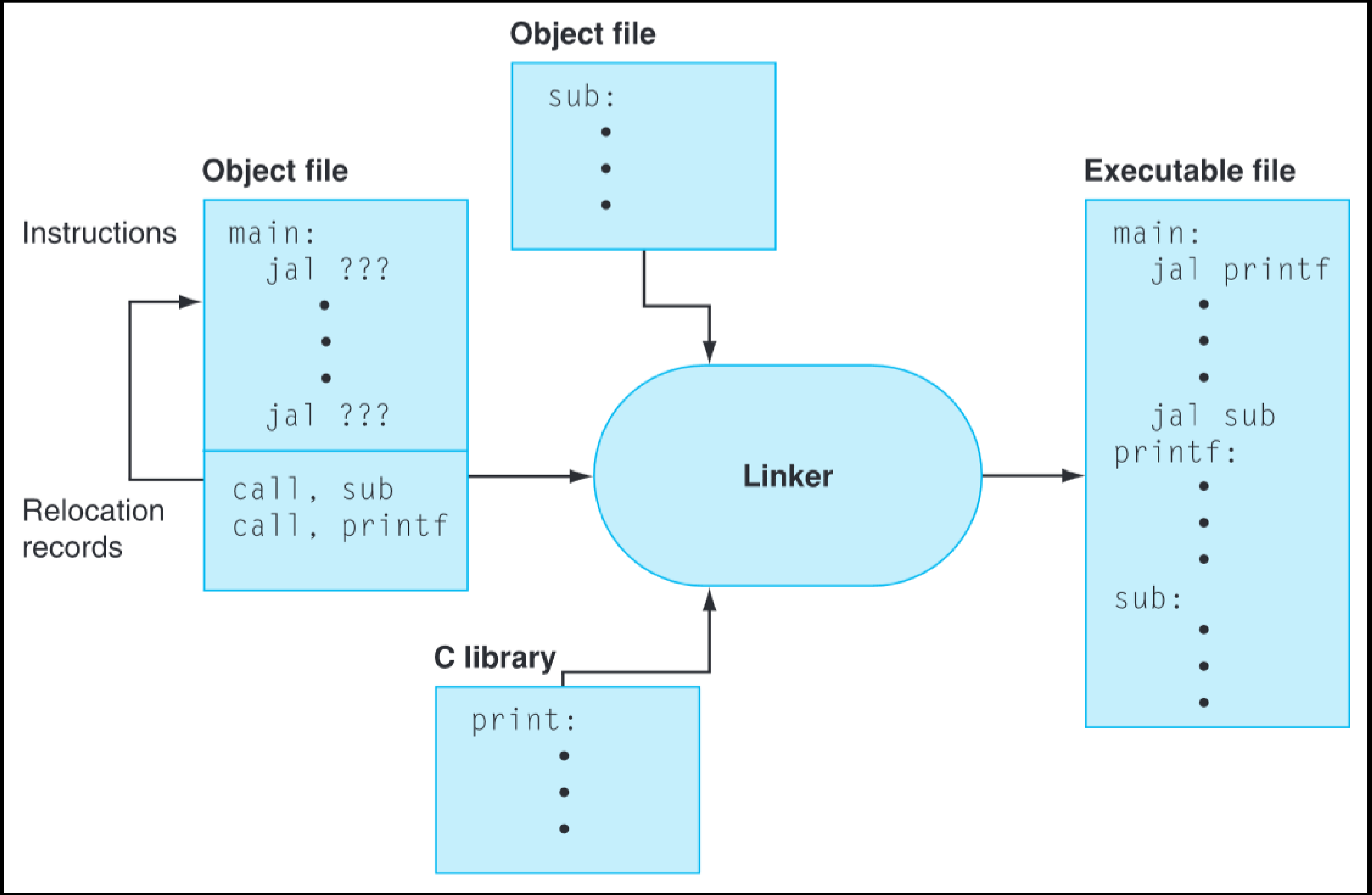
For Unix systems, the object file contains:

- An *object file header* describing the size and position of the other portions of the object file.
- The *text segment* containing the machine instructions.
- The *data segment* containing the data values.
- Relocation information identifying the list of instructions and data words that depend on absolute addresses.
- A *symbol table* containing global labels and associated addresses in object file and the list of unresolved references.
- Debugging information to allow a symbolic debugger to associate machine instruction addresses with source line statements and data addresses with variable names.

LINKING

- Linkers take object files and object libraries as input and produce an executable file as output.
- Linkers also resolve external references by either finding the symbols in another object file or in a library.
- The linker aborts if any external references cannot be resolved.
- The linker determines the addresses of absolute references using the relocation information in the object files.
- The executable has a similar format as object files with no unresolved references and no relocation information.

LINKING


Object file
sub:
Object file
Executable file
Instructions
main:
jal ???
jal ???
Relocation records
call, sub
call, printf
Linker
main:
jal printf
jal sub
printf:
sub:
C library
print:

LOADING

The loader copies the executable file (or a portion of it) from disk into memory so it can start executing.

- Reads the executable file's header to determine the size of the text and data segments.
- Allocates the address space for the process (text, static data, heap, and stack segments).
- Copies the instructions into the text segment and data into the static data segment.
- Copies arguments passed to the program onto the stack.
- Initializes the machine registers and stack pointer.
- Jumps to a start-up routine that will call the main function.

GCC EXAMPLE

Let's say I have three files – a class declared in exp.h and defined in exp.c, as well as a main.c file which uses the class.

```
$ ls
exp.c exp.h main.c
$ gcc -c exp.c
$ gcc -c main.c
$ ls
exp.c exp.h exp.o main.c main.o
$ gcc main.o exp.o -o exp_prog
exp.c exp.h exp.o exp_prog main.c main.o
```

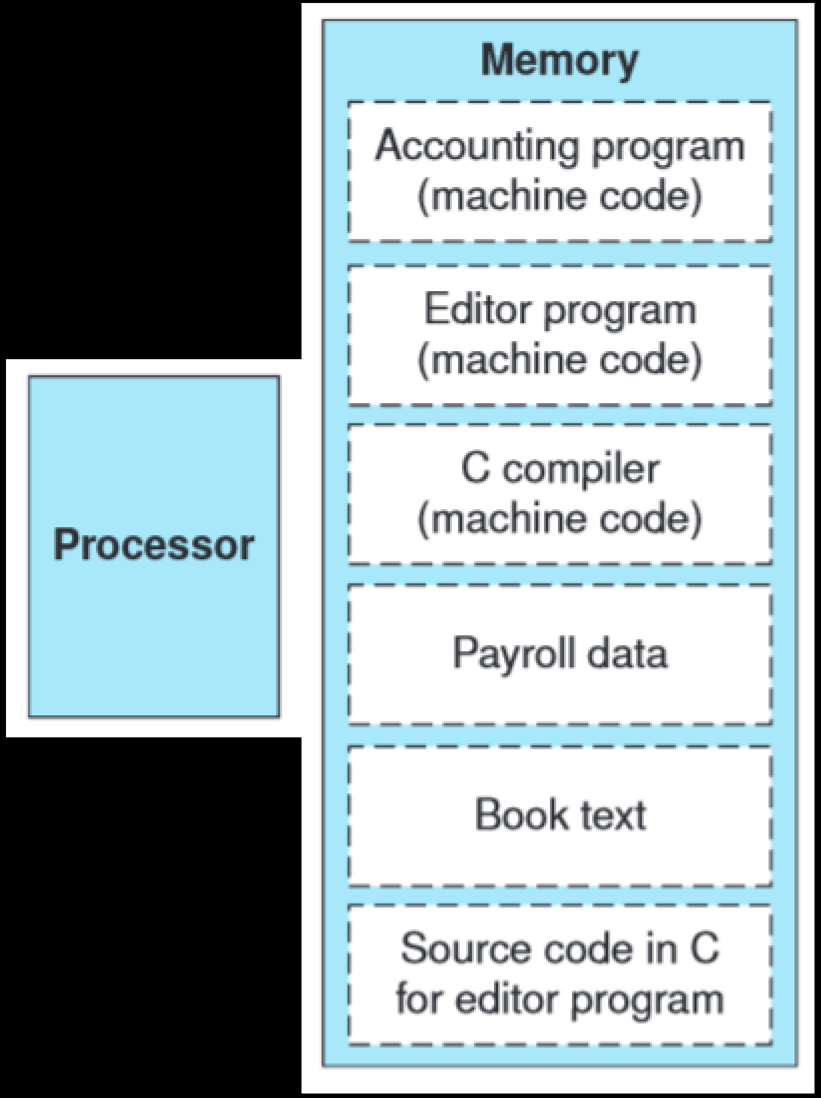
Preprocessing, Compiling, and Assembling the source code individually. Result is an object file.

Linking the object files together into an executable file.

You can check out the pre-processed version of your code with the –E option. Prints to stdout.
You can check out the assembly version of your code with the –S option. Check the *filename.s* file.

STORED PROGRAM CONCEPT

- Memory can contain both instructions and data and the computer is instructed to start executing at a specific location.
- Different programs can be loaded in different locations and the processor can switch between processes very quickly.


Memory
Accounting program (machine code)
Editor program (machine code)
C compiler (machine code)
Payroll data
Book text
Source code in C for editor program
Processor