LECTURE 4: C PROGRAMMING

Computer Systems and Networks

Dr. Pallipuram
(vpallipuramkrishnamani@pacific.edu)

Deadlines

Lab 2 September 13th, 2017

Lab 3 September 19th, 2017

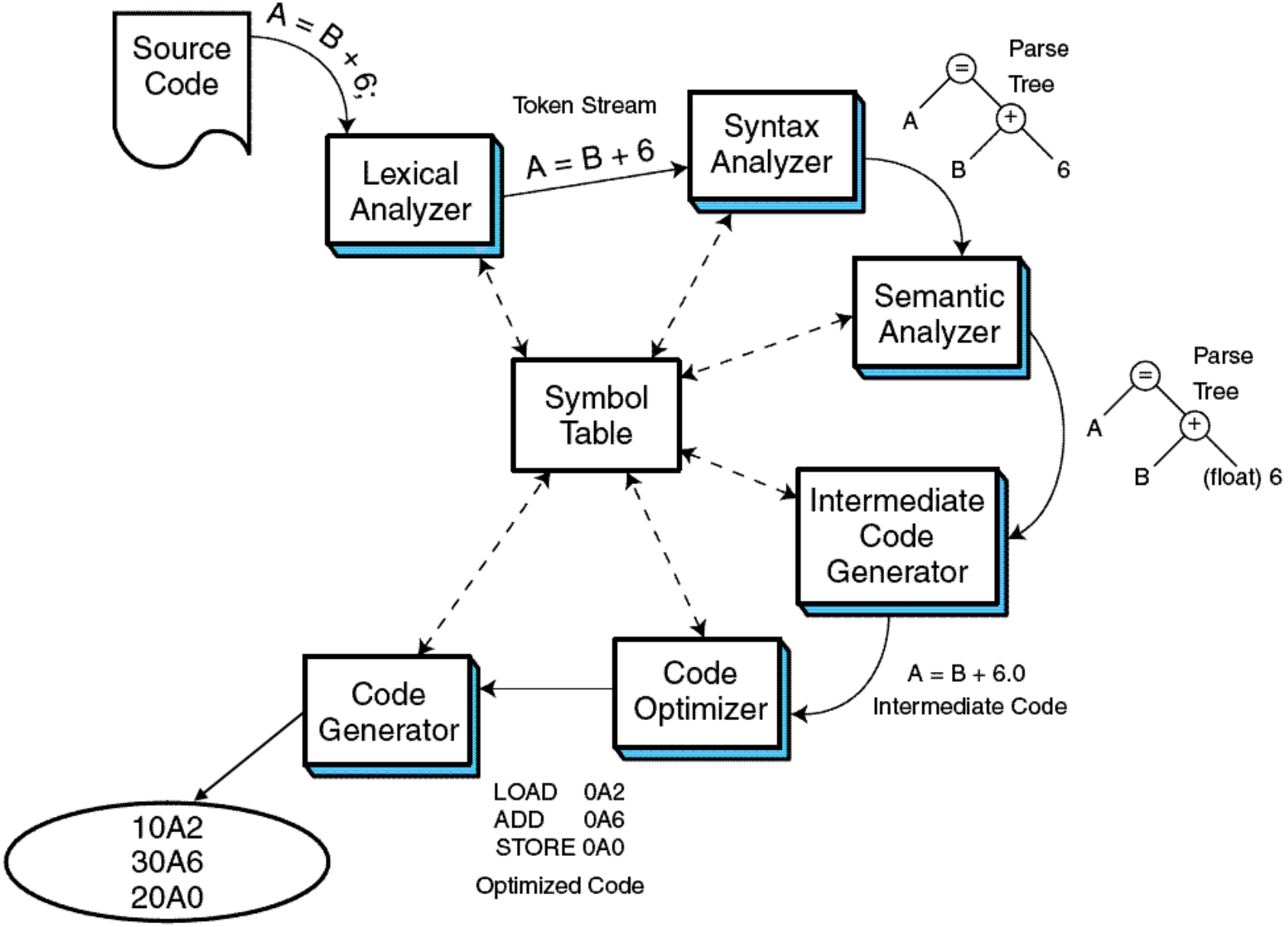
Today's Class

- The C compiler and Makefile
- `printf, scanf`, and format specifiers
- Arrays: one-dimensional and multi-dimensional
- Introduction to Pointers

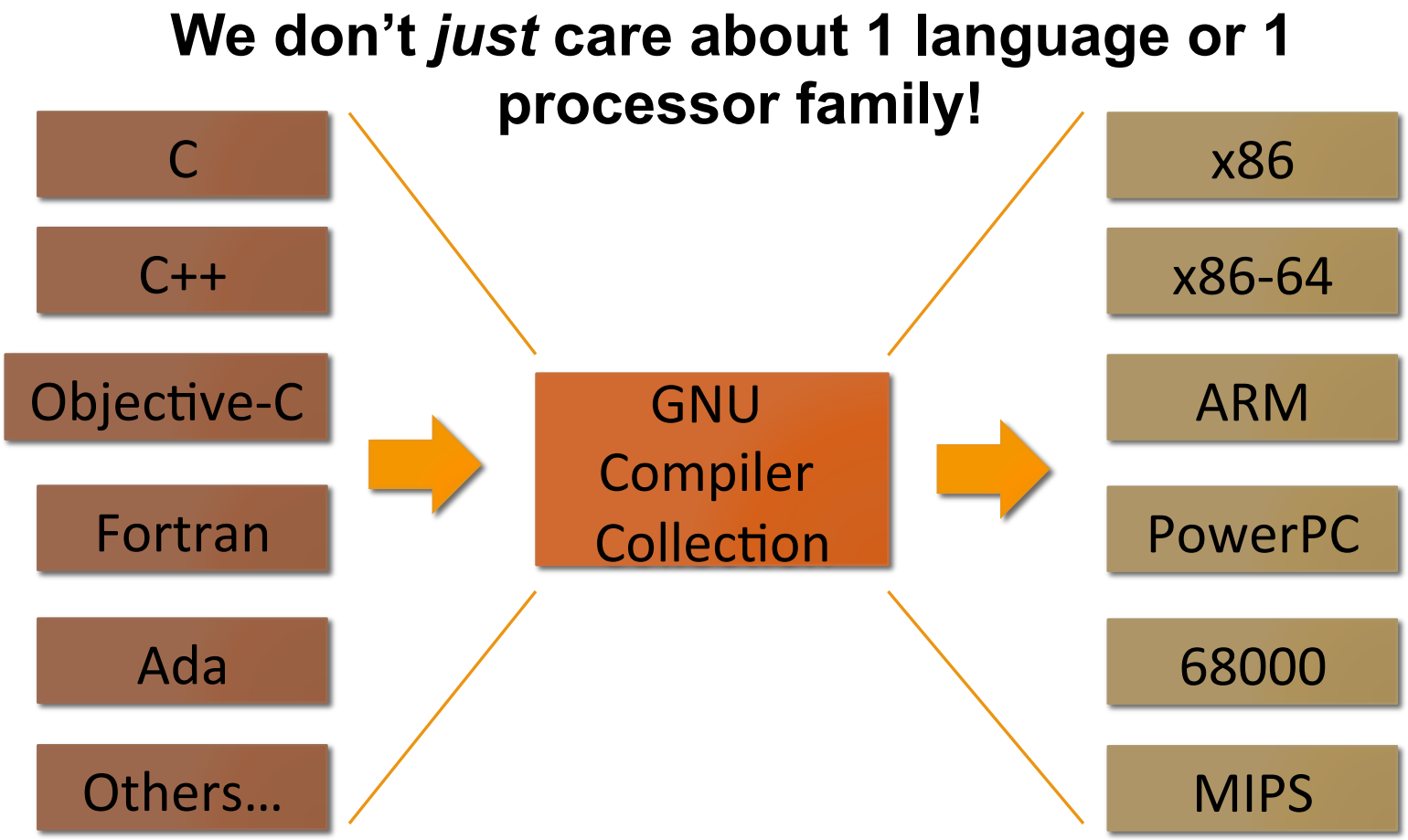
A simple code compilation

```
unix> gcc –o myprog main.c
unix> ./myprog
```

Compiler Operation



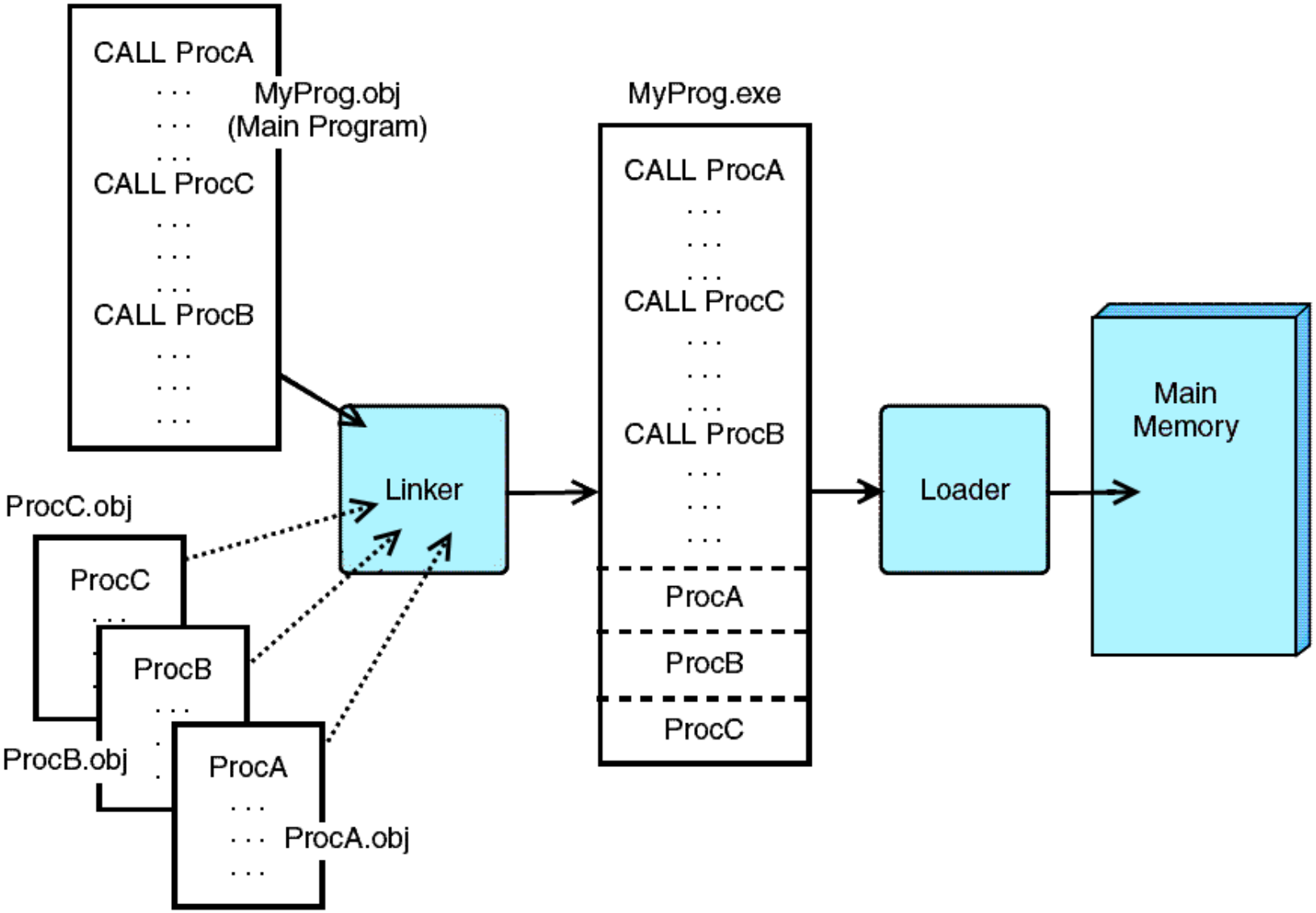
Why So Many Compilation Steps?



When your program has multiple files

```
unix> gcc main.c file2.c -o MyProg
unix> ./MyProg
```

Linker + Loader



Result: Program binary (saved on disk)

```
1101111010100000010100000011011110101000
0001010000001101111010100000010100000001
1011110101000000101000000110111010100000
0010100000011011110101000000101000000011
0111010100000010100000011011110101000000
0101000000110111101010000001010000000110
1110101000000101000000110111010100000000
1010000001101111010100000010100000001101
1101010000001010000001101111010100000001
```

Operating System

Security: OK to run file?

Memory management: Find space and create new virtual memory region for this program

Filesystem: Retrieve program binary code from disk

Loader: Place program binary code into memory

Scheduler: Find CPU time for program to run

Context switch – Program starts running

Problem 1

Without Google search, can you identify the linux command to link object files.

Makefile

Goal: Compile our program with one command:

```
unix>  make
```

A **Makefile** is a **text file** that specifies how to compile your program

- The `make` utility reads the Makefile
- You'll learn how this file works in Lab 3

An Intermediate Makefile

```
all: factorial_program
factorial_program: main.o factorial.o output.o
	gcc main.o factorial.o output.o -o
factorial_program
main.o: main.c
	gcc -c main.c
factorial.o: factorial.c
	gcc -c factorial.c
output.o: output.c
	gcc -c output.c
clean:
	rm -rf *.o factorial_program
```

An Advanced Makefile

```
# The variable CC specifies which compiler will
be used.
# (because different unix systems may use
different compilers)
CC=gcc

# The variable CFLAGS specifies compiler options
#   -c :    Only compile (don't link)
#   -Wall:  Enable all warnings about lazy /
dangerous C programming
CFLAGS=-c -Wall
# The final program to build
EXECUTABLE=factorial_program

# ------------------------------------
```

```
all: $(EXECUTABLE)

$(EXECUTABLE): main.o factorial.o output.o
	$(CC) main.o factorial.o output.o -o $
(EXECUTABLE)

main.o: main.c
	$(CC) $(CFLAGS) main.c

factorial.o: factorial.c
	$(CC) $(CFLAGS) factorial.c

output.o: output.c
	$(CC) $(CFLAGS) output.c

clean:
	rm -rf *.o $(EXECUTABLE)
```

C Tutorial

Print with printf()

```
printf("This is a string\n");

printf("The integer is %i\n", num);

printf("The floating-point values are %g
and %g\n", num1, num2);
```

Output with printf()

Format "Type" Code	Corresponding Variable Type
`d` or `i`	int (interpret as signed 2's comp)
`u`	int (interpret as unsigned)
`x`	int (print as hexadecimal)
`f` or `g`	float/double
`c`	char
`s`	string (null-terminated array of chars)
`p`	An address to which the pointer points

Prefix with `l` or `ll` (i.e. "long" or "long long" for larger 64-bit data types)

- Lots of formatting options not listed here…
  - # of digits before / after decimal point?
  - Pad with zeros?

Input with scanf()

Input from console

```
scanf("%d %c", &myint, &mychar)
```

Requires the **address** of the destination variable

- Use the `&` operator to obtain address

Problem 2 – Read the man pages for printf and scanf

Man(ual) pages exist for common programming functions too

```
unix>  man printf

unix>  man scanf
```

Arrays

Arrays

Contiguous block of memory

You can have arrays for int, char, float, double, structures…

```
int myarray[5]; //static declaration
```

NOTE: Name of the array holds the address of the first element

address:	4	8	12	16	20
	myarray[0]	myarray[1]	myarray[2]	myarray[3]	myarray[4]

```
printf("%p",myarray); //prints what?
```

2-dimensional arrays

```
int myarray[5][5]; //static declaration
```

Memory map:

Address: 4 myarray[0][0]	Address: 8	Address: 12	Address: 16	Address: 20
Address: 24	Address: 28 myarray[1][1]	Address: 32	Address: 36	Address: 40
Address: 44	Address: 48	Address: 52	Address: 56	Address: 60
Address: 64	Address: 68	Address: 72 myarray[3][2]	Address: 76	Address: 80
Address: 84	Address: 88	Address: 92	Address: 96	Address: 100

Problem 3: Looping through an array

Consider a 3-D array, `int image[256][256][3]` for an RGB color image. The first subscript denotes the number of rows, the second subscript denotes the number of columns, and the third subscript denotes the number of color channels. For example, a pixel at row `i` and column `j` will have R value as `image[i][j][0]`, G value as `image[i][j][1]`, and B value as `image[i][j][2]`. Any pixel has yellow color if it's R and G values are 255 and B value is 0. Write a for loop to search for the location of the very first yellow pixel in `image`. The search should terminate once the yellow pixel is found. Search in row-wise manner.

Pointers

Pointers are special variables that hold/store memory addresses of other variables.

When a pointer, say iptr, holds the address of an integer variable, say ivar, then we say: “iptr is an integer pointer that points to ivar.”

```
int ivar=45;
int *iptr; iptr = &ivar; //iptr points to ivar
```

‘&’ is ‘address of variable’ operator. For example, `&ivar` translates to: “address of variable ivar”.

‘*’ is ‘value at address stored in pointer’ operator. For example, `*iptr` translates to: “value at address stored in pointer iptr”.

We can have a ‘multiple’ pointer

Example pointer declaration:

```
int *iptr; //an integer pointer that will point
to an integer

int **dptr; //A double pointer that will point
to an integer pointer


int ***tptr; //A triple pointer pointing to a
double pointer.


int ****quadptr //
```

Problem 4

Consider the variables below:

Variable Name: ivar	Pointer variable name: iptr
value: 5	value:
Address: 0xFFABCD	Address: OxAFABAD

```
int ivar=5;
int *iptr;
iptr = &ivar;
printf("\n %u",ivar);  prints_________
printf("\n %u",&ivar);   prints_________
printf("\n %u",&iptr);   prints_________
printf("\n %u",*iptr);   prints_________
```

Problem 5

Variable Name: ivar	Pointer variable name: iptr	Pointer variable name: dptr
value: 5	value:	value:
Address: 0xFFABCD	Address: OxAFABAD	Address: OxFFACBD

```
int ivar=5;
int *iptr;
int **dptr;
iptr = &ivar;
dptr=&iptr;
printf("\n %u",dptr);  prints_________
printf("\n %u",iptr);  prints_________
printf("\n %u",*dptr);  prints_________
printf("\n %u",**dptr);  prints_________
printf("\n %u",&dptr);  prints_________
printf("\n %u",*(&(iptr)));  prints_________
```

Next Class

Pointer basics

Pointers and Arrays
- Dynamic Allocation

Pointers and Structures
- Linked Lists
- Binary trees

File I/O in C

A C challenge (with a reward ☺)