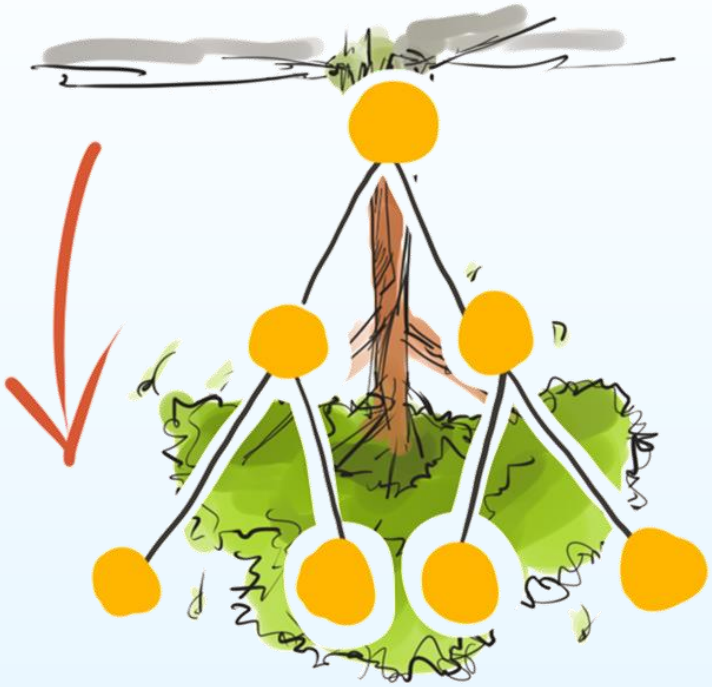


# Lecture 1: C Programming (Part I)

01204212 Abstract Data Types and Problem Solving

Department of Computer Engineering
Faculty of Engineering, Kasetsart University
Bangkok, Thailand.

Department of Computer Engineering Kasetsart University

MIKE LABORATORY

# Outline

- Programming Overview
- Statement
- Expression
- Variable
- Data Types
- Selection Control Structure

# A computer program

- A **computer program** is a sequence of **instructions** to be executed by computers.
- Examples of computer programs in various forms:

```
0001 1001
1001 1110
1000 1011
1100 1011
1110 0010
1001 0111
1100 1011
1110 0010
1001 0111
1100 1011
```

Machine instructions

```
MOV   AX,10
SUB   BX,AX
MOV   [DX],AX
JMP   200
MOV   CX,5
MOV   AX,10
MUL   AX,CX
CMP   BX,AX
JLE   500
JMP   400
```

Instructions in assembly language

```
int i, sum = 0;
for (i=0; i<100; i++)
  sum += i;
```

Instructions in C programming language

More readable

# High-Level Language

- Easy to learn, understand, write program
  - Program instructions are English-like statements
- Safeguards against bugs
  - Rules and conditions are enforced at compile-time or run-time
- Built-in library functions
  - Many built-in functions are provided to perform specific tasks of new programs
- Machine independence
  - Operations do not depend on instruction set
    - e.g., can write "a = b * c", even though LC-3 processor does not have a multiply instruction
  - A program written in one type of computer can be executed on another type of computer

# Programming Paradigms

- Procedural Programming
  - Paradigm that uses a list of instructions to tell the computer what to do step-by-step (i.e., top-down approach)
  - It relies on procedures, a.k.a. subroutines, containing a series of computational steps to be carried out
  - Languages: C, Fortran, Cobol, Pascal, …
- Object-Oriented Programming
  - Approach to problem-solving where all computations are carried out using objects
  - Object is a component of a program that knows how to perform certain actions and how to interact with other elements of the program
  - Languages: C#, Java, …

# Interpretation vs. Compilation

- Different ways of translating high-level language
- Interpretation
  - Convert program into machine code when the program is run
  - Execute each statement at a time
  - Tool: interpreter
  - Languages: Perl, Bash, PHP, Python, JavaScript, …
- Compilation
  - Convert the whole program into machine code before running
  - Perform optimization over multiple statements
  - Tool: compiler
  - Languages: C, C++, C#, …

# Interpretation vs. Compilation

- Different ways of translating high-level language
- Interpretation

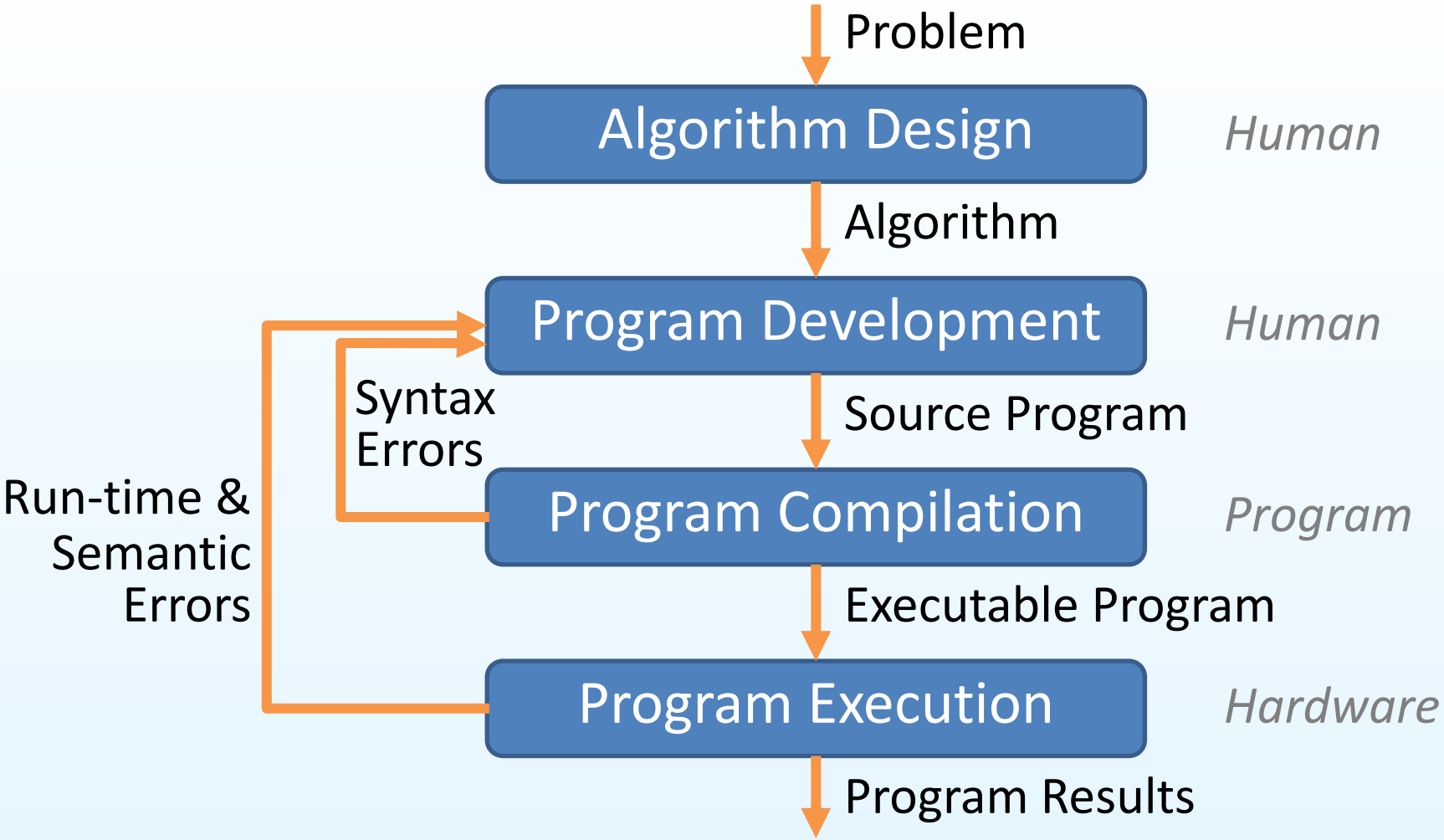
```
repeat 100 times
   n = 10
   sum = sum + n
print sum
```

- Compilation

```
n = 10
repeat 100 times
   sum = sum + n
print sum
```

**What are differences?**

# Development Process



# C Compilation Process

## Preprocessor

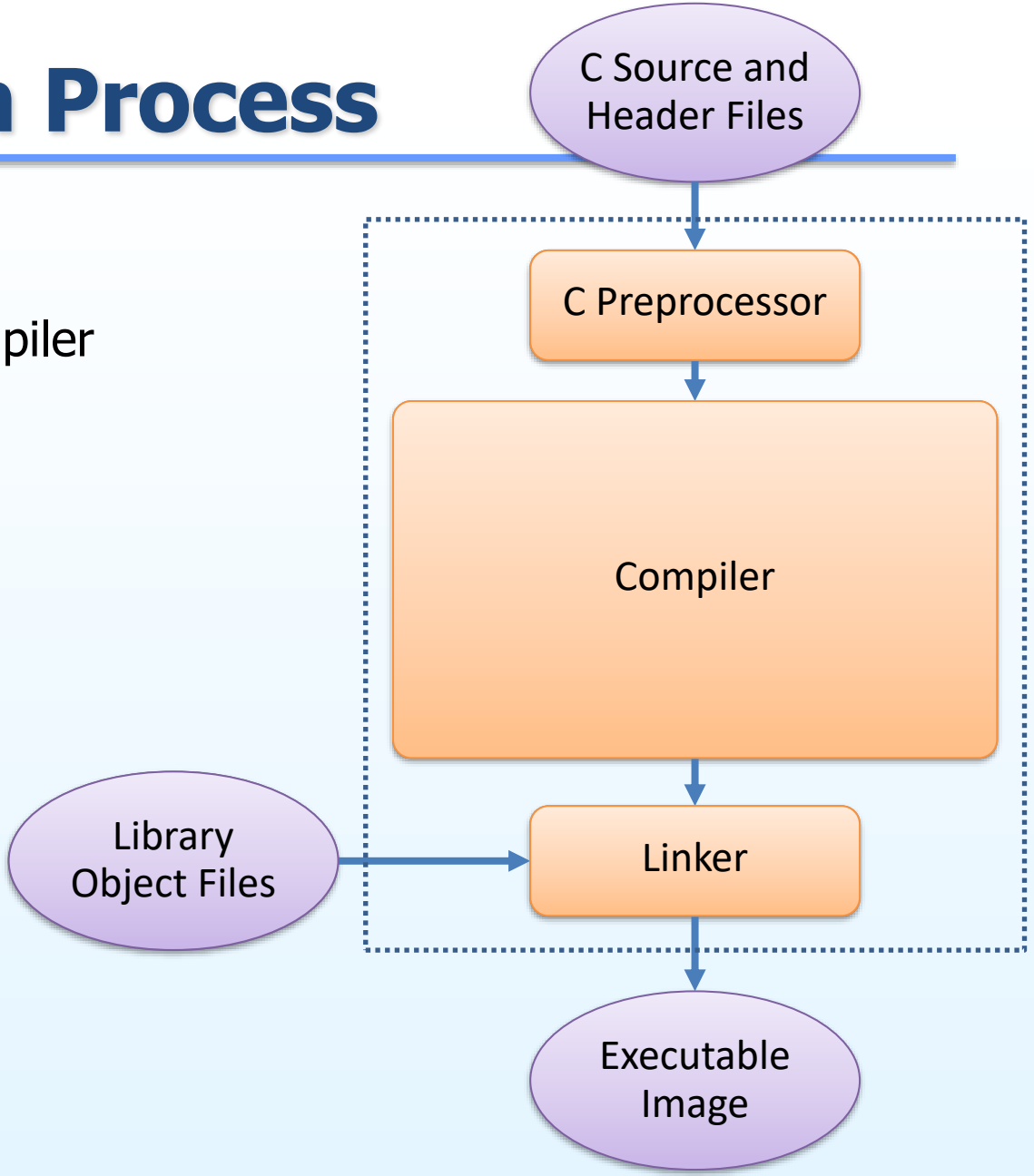
- Expand source code to a simpler form for the compiler
- Expand macros
- Strip out comments
  - ➡ Still C code

## Compiler

- Generate object file
  - ➡ Machine instructions

## Linker

- Combine object files (including libraries)
  - ➡ Executable image



# C Compilation Process

## Source Code Analysis

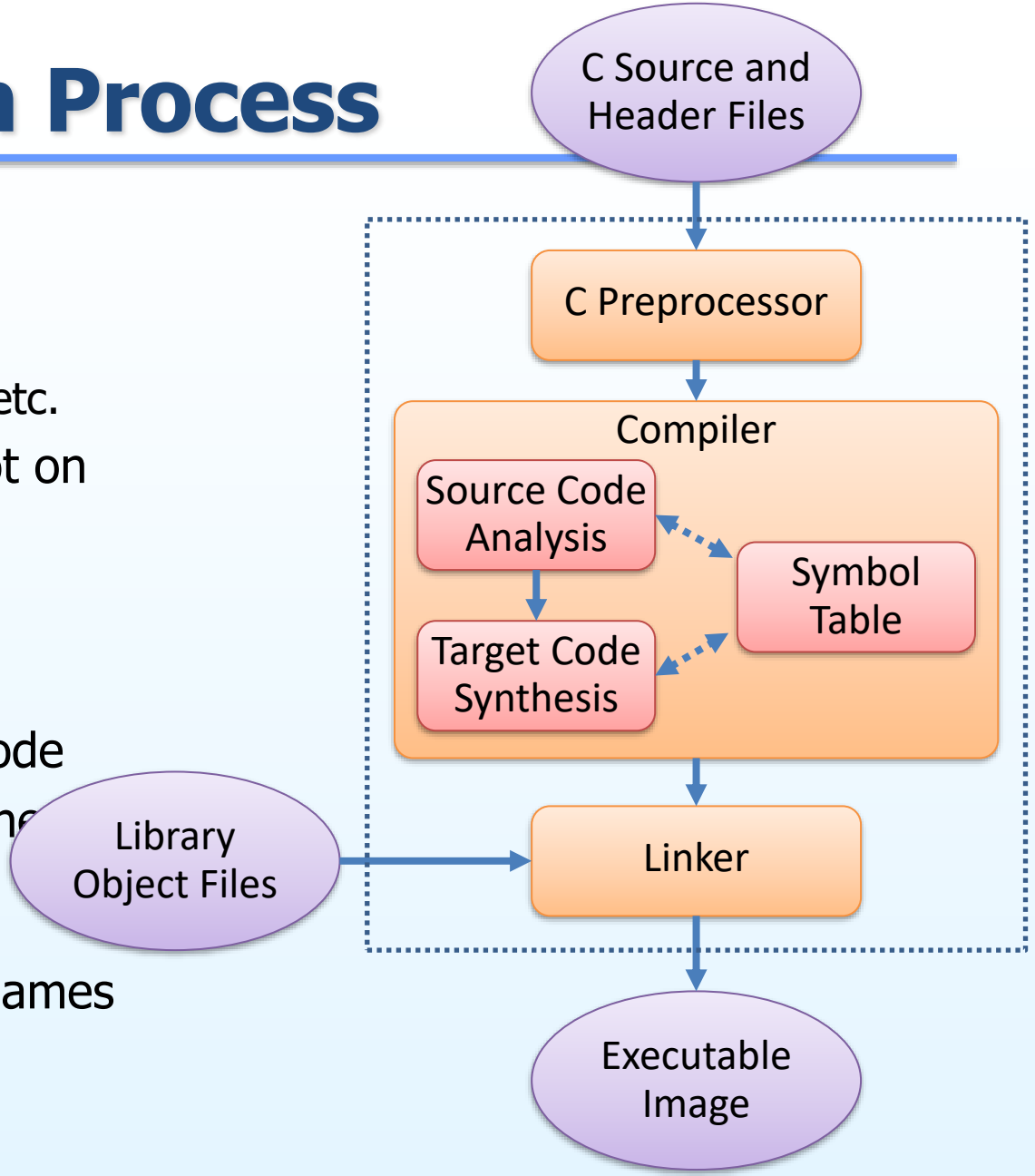
- Parse program to pieces
  - Variables, expressions, statements, functions, etc.
- Depend on language (not on target machine)

## Target Code Synthesis

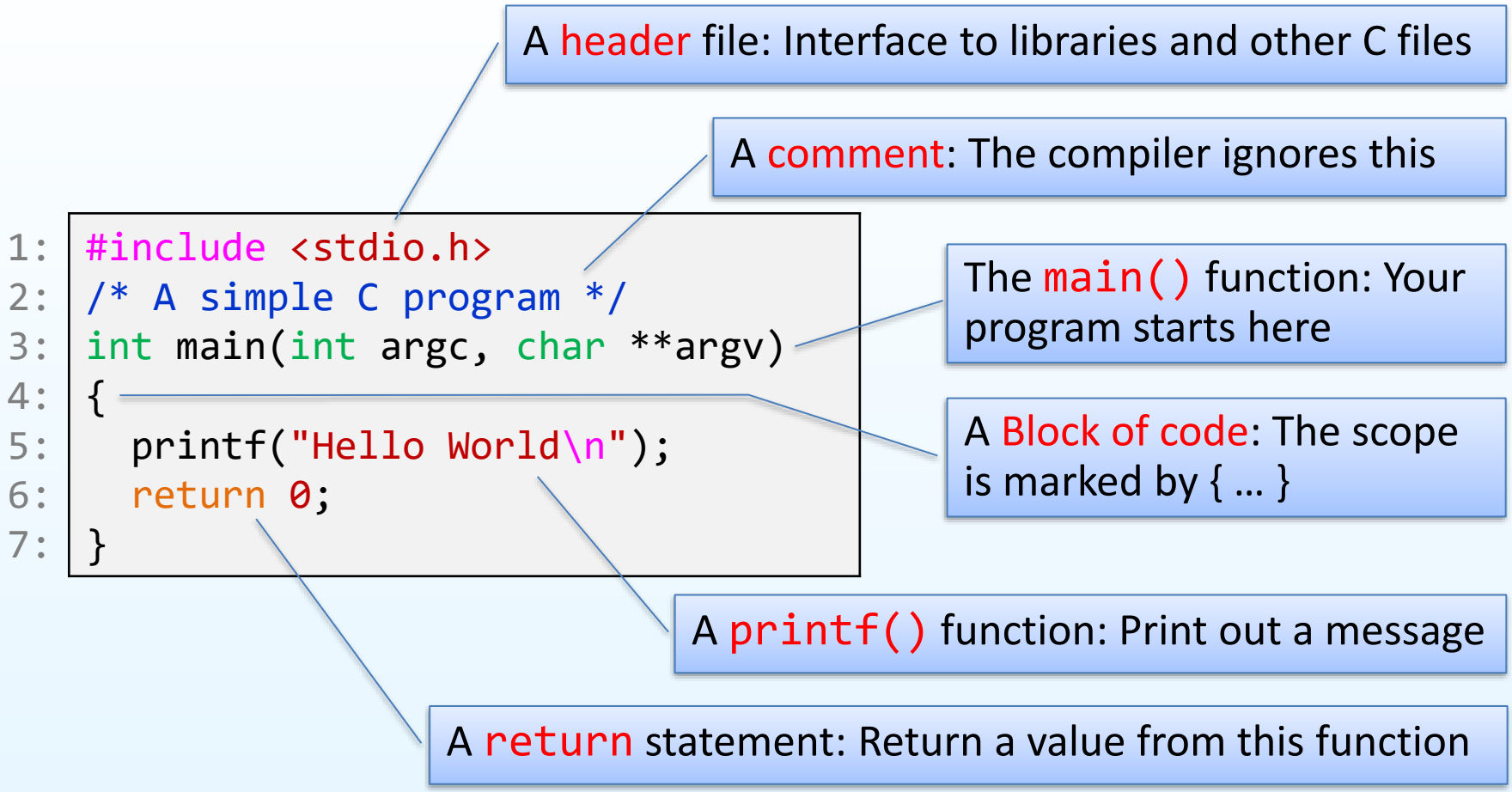
- Generate machine code
- May optimize machine code
- Depend on target machine

## Symbol Table

- Map between symbolic names and items



# First C Program with "Hello World"



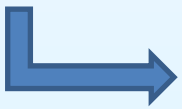
# A Quick Digression about Preprocessor

```c
#include <stdio.h>
/* A simple C program */
int main(int argc, char **argv)
{
  printf("Hello World\n");
  return 0;
}
```

Preprocessing

```c
__extension__ typedef unsigned long long int __dev_t;
__extension__ typedef unsigned int __uid_t;
__extension__ typedef unsigned int __gid_t;
__extension__ typedef unsigned long int __ino_t;
__extension__ typedef unsigned long long int __ino64_t;
__extension__ typedef unsigned int __nlink_t;
__extension__ typedef long int __off_t;
__extension__ typedef long long int __off64_t;
extern void flockfile (FILE *__stream);
extern int ftrylockfile (FILE *__stream);
extern void funlockfile (FILE *__stream);
int main(int argc, char **argv)
{
  printf("Hello World\n");
  return 0;
}
```

Compiling and Linking



Executable File “a.out”

In preprocessing step,

- Parse included files (`#include`)
- Expand macros (`#define`)
- Strip out comments (`/* */`, `//`)
- Join continued lines (`\`)

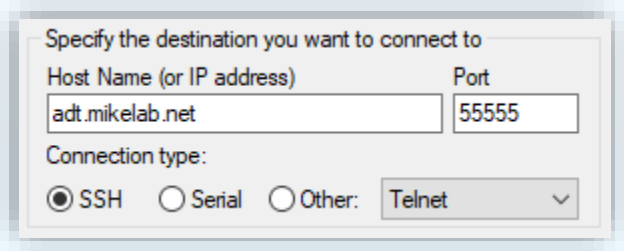
In compiling step,

- Convert to binary code

# The ADT Class Environment

- Server: adt.mikelab.net
- User: **b**<your 10-digit student ID>
- Pass: … Let you know in the class

- For Windows, use the Putty program




- For MAC or Linux, use the terminal application

```
$ ssh  <user>@adt.mikelab.net  -p  55555
```

# The ADT Class Environment

Cannot be used

- Use the vi Editor … see tutorial
- Special commands for your assignment tasks
  - Show the status of your work

```
$ hw-status  [--all]
```

  - Submit your job

```
$ hw-send  LABNAME  FILENAME
```

  - Retrieve your job that have already been submitted

```
$ hw-load  LABNAME
```

# Writing and Running Program

1. Write a C program, named "hello.c"

```c
#include <stdio.h>
/* A simple C program */
int main(int argc, char **argv)
{
  printf("Hello World\n");
  return 0;
}
```

2. Convert the program to an executable file

```
$ gcc hello.c
```

option: -o specify the executable name
-Wall enables all the warnings
-c produce only the compiled code
-E produce only the preprocessor output
-S produce only the assemble code
-save-temps produce all the intermediate files
-l link with shared libraries

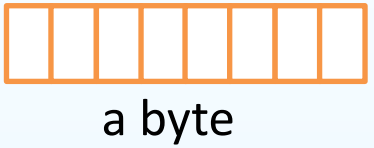
3. Run the program

```
$ ./a.out
Hello World
$
```

# Computer Memory

- The smallest unit of information storage on a computer, called bit
  - Can be either 0 or 1


- A group of eight bits, called byte
  - Store a value ranging from 0 to 255



# Computer Memory

- Memory is like a big table of slots where bytes can be stored
- 1-byte value can be stored in each slot, referred by its address
- Some logical data values span more than one slot:
  - E.g., the character string `"Hello\n"`
- A data type names a logical meaning to a span of memory:
  - `char` a single character (1 byte)
  - `int` signed integer (4 bytes)
  - `float` floating point (4 bytes)
  - `double` double-precision floating point (8 bytes)

high …

| Address | Value |
|---|---|
| 0x7fffb5 | 1 byte |
| 0x7fffb4 | 00000000 (0 = '\0') |
| 0x7fffb3 | 00001010 (10 = '\n') |
| 0x7fffb2 | 01101111 (111 = 'o') |
| 0x7fffb1 | 01101100 (108 = 'l') |
| 0x7fffb0 | 01101100 (108 = 'l') |
| 0x7fffaf | 01100101 (101 = 'e') |
| 0x7fffae | 01001000 (72 = 'H') |
| 0x7fffad | |
| 0x7fffac | 4-byte integer |
| 0x7fffab | |
| 0x7fffaa | |
| 0x7fffa9 | |
| 0x7fffa8 | |

low …

# Statement

- A statement is a complete command to ask the computer to do something

- Can be a single-line command, ending with a semicolon ;

```
printf("Hello World\n");
```

or

```
return 0;
```

- Can be a block of codes, marked by the braces { ... }

```
for (i=0; i<10; i++)
{
  printf("Hello World\n");
  sleep(1);
}
```

# Output Statement: `printf()` Function

- The built-in I/O functions are provided in C standard library "`stdio.h`"
- Here, we use the `printf()` function to formatted output to standard output

**Syntax:**

```
printf(ctrl_string, var_list);
```

- Examples:

```
printf("This is simple text for output\n");
printf("I am %d years old\n", age);
printf("The date is %3d%3d%6d\n", 2, 5, 2003);
printf("The answer is %5.2f\n", someFloatValue);
```

# Identifier

- A name for some C elements, such as variables or functions

- Some common rules
  - Consist of only alphabet, digits, and underscores
  - Cannot begin with a digit
  - Must not be a reserved word
  - Be case sensitive

# Reserved Words (Keywords)

| Keywords | | | |
|---|---|---|---|
| auto | double | int | struct |
| break | else | long | switch |
| case | enum | register | typedef |
| char | extern | return | union |
| const | float | short | unsigned |
| continue | for | signed | void |
| default | goto | sizeof | volatile |
| do | if | static | while |

# Variable

- A variable names a place in memory where you store a value of a certain type
- You first define a variable before using by giving it a name and specifying the type, and optionally an initial value

**Syntax:**

```
datatype variable;
datatype variable = value;
```

# C Data Types

- A data type determines the type and size of data associated with a variable

| Data Type | Size (bytes) | Format Specifier (placeholder) |
|---|---|---|
| char | 1 | %c |
| short | 2 | %hd, %hi, %d, %i |
| int | 4 | %d, %i |
| long | 8 | %ld, %li |
| float | 4 | %f |
| double | 8 | %lf, %f |

1) Try to use %d for char!

2) Explore other data types by yourself

# OK, We're Back … Variable Declaration

```
char x = 'e';
char y;
int sum;
```

**What are the values of y and sum?**

| Symbol | Address | Value |
|---|---|---|
| | … | |
| | 0x7fffb2 | |
| sum | 0x7fffb1 | ???????? |
| | 0x7fffb0 | ???????? |
| | 0x7fffaf | ???????? |
| | 0x7fffae | ???????? |
| | 0x7fffad | |
| | 0x7fffac | |
| x | 0x7fffab | 01100101 (101 = 'e') |
| y | 0x7fffaa | ???????? |
| | 0x7fffa9 | |
| | 0x7fffa8 | |
| | … | |

# Input Statement: `scanf()` Function

- The built-in I/O functions are provided in C standard library "`stdio.h`"
- Here, we use the `scanf()` function to formatted input from standard input

**Syntax:**

```
scanf(ctrl_string, var_list);
```

- Examples:

```
scanf("%d %d", &width, &height);
scanf("%c%c%c", &a, &b, &c);
scanf("I am %d years old", &age);
```

# Arithmetic Expression

- An expression is something that can be evaluated to a type and a value
- An arithmetic expression can be evaluated to a numerical value

- Examples:

```
1
1+2
(1+2)/3
```

# Some C Operators

- Arithmetic operators
  - Unary: plus(+), minus(-)
  - Binary: addition(+), subtraction(-), multiplication(*), division(/), modulus(%)

**What is the value of 1/2?**

- Assignment operators
  - Assignment: =
  - Shortcut assignment: +=, -=, *=, /=, %=

- Increment and decrement operators
  - Unary prefix: ++*var*, --*var*
  - Unary postfix: *var*++, *var*--

# Precedence and Associativity

high

low

| Type | Operator | Associativity |
|---|---|---|
| Unary postfix | `++ --` | left to right |
| Parentheses | `()` | left to right |
| Unary prefix | `++ -- + -` | right to left |
| Multiplicative | `* / %` | left to right |
| Additive | `+ -` | left to right |
| Assignment | `= += -+ *= /+ %=` | right to left |

**Quiz:**

```
1:  #include <stdio.h>
2:  int main(void)
3:  {
4:    int x = 2, y = 5;
5:    x += ++y;
6:    printf("%d %d\n", x, y);
7:    x += y++;
8:    printf("%d %d\n", x, y);
9:    return 0;
10: }
```

**What is the output of this program?**

# Data Type Conversion

```
int    x = 10;
double y = 20.5;
```

- Arithmetic promotion (implicit)
  - Operators convert their operand automatically

```
y = y + x;
```

- Casting (explicit)
  - Conversion is performed by the programmer via an explicit type

```
x = (int)y;
```

# Exercise 1 (5 mins.)

Write a program that asks the user to enter the radius of a circle and then computes and displays the circle's area.

Use the formula:

$$Area = PI \times Radius \times Radius$$

where *PI* is the constant macro 3.14159.

# Fundamental Flow Controls

- Sequence
- Subroutine (function)
- Selection: `if`, `if-else`, `switch`
- Repetition: `for`, `while`, `do-while`

# More C Expressions and Operators

- A Boolean expression can be evaluated to a Boolean result
  - **NOTE:** In C program, 0 refers to False and 1 refers to True

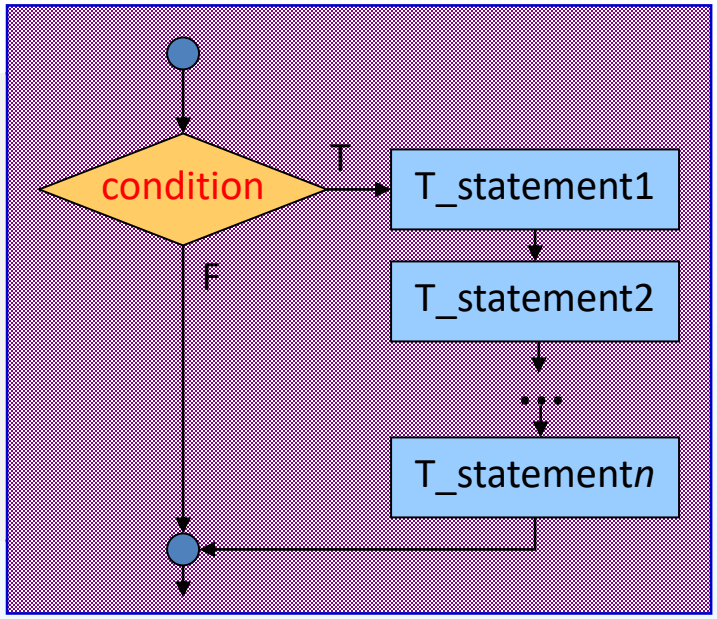

- Boolean operators
  - Relational: ==, !=, >, <, >=, <=
  - Logical: NOT(!), AND(&&), OR(||)
  - Bitwise: NOT(~), AND(&), XOR(^), OR(|)

**What is the value of the expression !-2<3&&3<2?**

# Selection: The `if` Statement

**Syntax:**

```
if (condition)
{
   T_statement1;
   T_statement2;
   ...
   T_statementn;
}
```

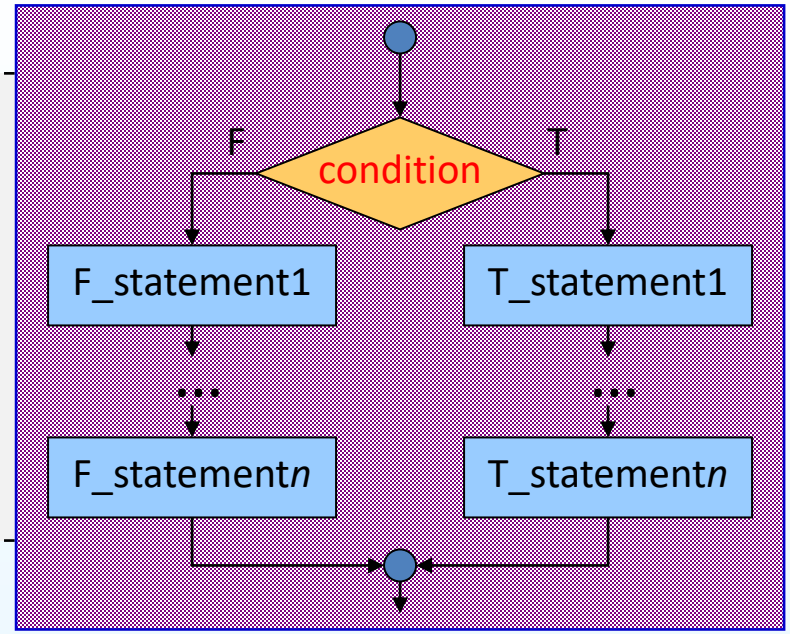



- Use the `if` keyword
- The statements are performed if the condition is True (non-zero value), otherwise they are skipped
- The braces `{}` are used to determine a block
  - Can be omitted if there is only one statement to be performed

# Selection: The `if-else` Statement

**Syntax:**

```
if (condition) {
   T_statement1;
   ...
} else {
   F_statement1;
   ...
}
```




- Use the `if` and `else` keywords
- Specify which statements to be performed when the condition is either True or False
- The braces {} are used to determine a block
  - Can be omitted if there is only one statement to be performed

# Exercise 2 (5 mins.)

Write an interactive program that contains an `if` statement that computes the area of either a square ($area = side^2$) or a triangle ($area = 1/2 * base * height$) after prompting the user to type the first character of the figure name ($S$ or $T$).

# Selection: The ternary Operator

- A ternary operator is a basic conditional expression

**Syntax:**

```
condition ? exp1 : exp2;
```

- The expression will evaluate to *exp*1 if the condition is True, and otherwise to *exp*2

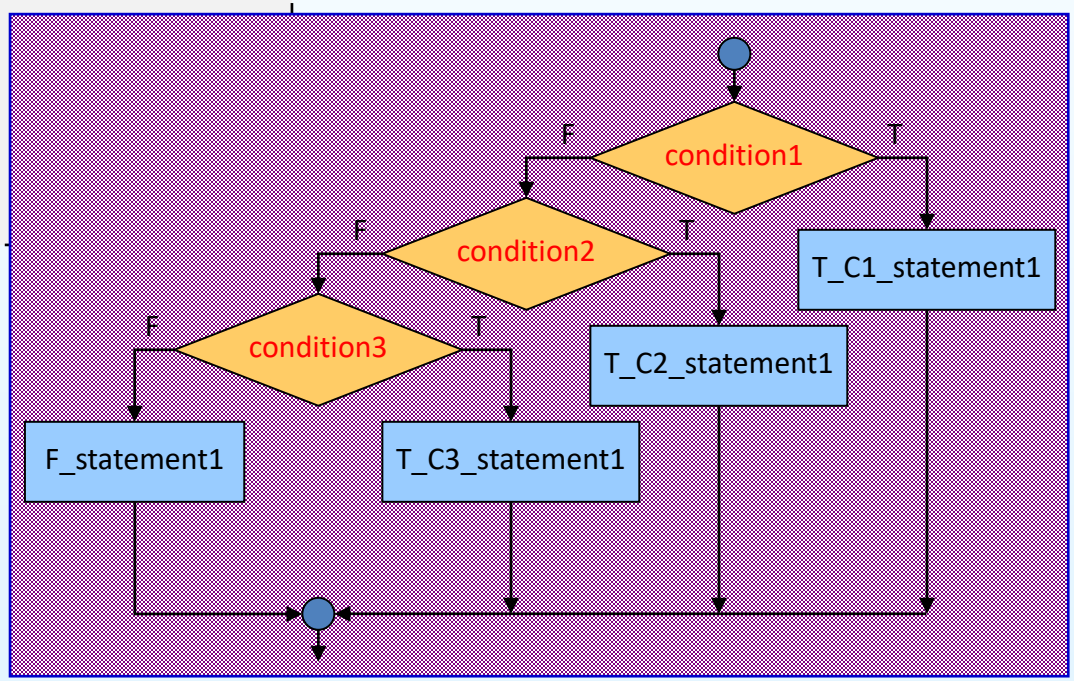
- Examples:

```
absdiff = y > x ? y - x : x - y;
grade >= 50 ? printf("Passed\n") : printf("Failed\n");
```

# Nested Selection

**Syntax:**

```
if (condition1) {
   T_C1_statement1;
} else if (condition2) {
   T_C2_statement1;
} else if (condition3) {
   T_C3_statement1;
} else {
   F_statement1;
}
```



# Examples: Nested Selection

**Code Fragment #1:**

```
1: if ((letter >= 'A') && (letter <= 'Z'))
2:   if (number >= 10)
3:     printf("*****\n");
4:   else
5:     printf("#####\n");
```

**Code Fragment #2:**

```
1: if ((letter >= 'A') && (letter <= 'Z'))
2:   if (number >= 10)
3:     printf("*****\n");
4: else
5:   printf("#####\n");
```

What is the output if

1) letter is 'B' and number is 3

2) letter is 'b' and number is 3

# Exercise 3 (5 mins.)

Write a program to get the first character from user and then display the class of ships as the following decision table:

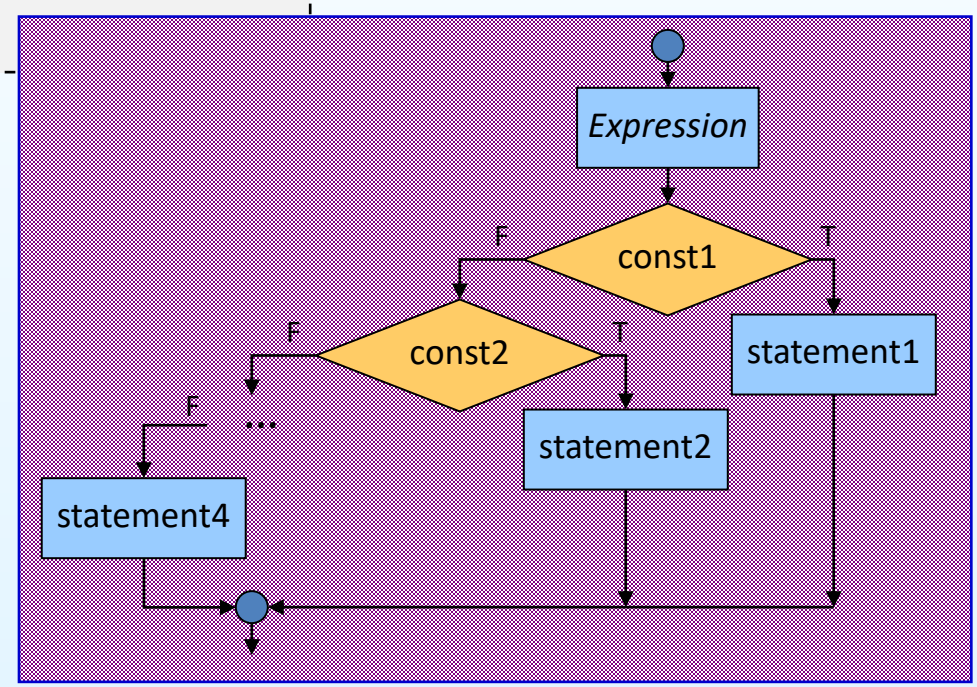
| Class ID | Ship Class |
|---|---|
| B or b | Battleship |
| C or c | Cruiser |
| D or d | Destroyer |
| F or f | Frigate |

# Selection: The `switch` Statement

**Syntax:**

```
switch (expression) {
  case const1: statement1; break;
  case const2: statement2; break;
  ...
  default: statementn; break;
}
```

- Use the **`switch`**, **`case`** and **`default`** keywords
- Group of the selected statements is performed, terminated by a **`break`**
- A valid expression may by of type `int`, `char`, `enum`.



# Examples: The `switch` Statement

**Code Fragment #1:**

```
1: switch (count) {
2:   case 0: printf("zero\n"); break;
3:   case 1: printf("one\n"); break;
4:   case 2: printf("two\n"); break;
5:   default: printf("more than two\n"); break;
6: }
```

**Code Fragment #2:**

```
1: switch (count) {
2:   case 0: printf("zero\n");
3:   case 1: printf("one\n");
4:   case 2: printf("two\n");
5:   default: printf("more than two\n");
6: }
```

What is the difference between two code fragments?

# Again, Exercise 3 (5 mins.)

Write a program to get the first character from user and then display the class of ships as the following decision table:

| Class ID | Ship Class |
|---|---|
| B or b | Battleship |
| C or c | Cruiser |
| D or d | Destroyer |
| F or f | Frigate |

Using the switch statement

# Any Question?

# Solution to Exercise 1

```
1:  #include <stdio.h>
2:  #define PI 3.14159
3:
4:  int main(void) {
5:    double radius = 0;
6:    double area = 0;
7:
8:    printf("Enter the radius: ");
9:    scanf("%lf", &radius);
10:   area = PI * radius * radius;
11:   printf("The circle's area is %lf\n", area);
12:
13:   return 0;
14: }
```

# Solution to Exercise 2

```c
#include <stdio.h>

int main(void) {
  char   figure = '\0';
  double side = 0, base = 0, height = 0, area = 0;

  printf("Enter the figure (S or T): ");
  scanf("%c", &figure);
  if (figure == 'S') {
    printf("Enter the side: ");
    scanf("%lf", &side);
    area = side * side;
  }
  if (figure == 'T') {
    printf("Enter the base and height: ");
    scanf("%lf %lf", &base, &height);
    area = 1.0/2 * base * height;
  }
  printf("The area is %lf\n", area);
  return 0;
}
```

# Solution to Exercise 3

```
1:  #include <stdio.h>
2:
3:  int main(void) {
4:    char class = '\0';
5:
6:    printf("Enter the class ID: ");
7:    scanf("%c", &class);
8:    if ((class == 'B') || (class == 'b'))
9:      printf("Battleship\n");
10:   else if ((class == 'C') || (class == 'c'))
11:     printf("Cruiser\n");
12:   else if ((class == 'D') || (class == 'd'))
13:     printf("Destroyer\n");
14:   else if ((class == 'F') || (class == 'f'))
15:     printf("Frigate\n");
16:   else
17:     printf("Unknow ship class %c\n", class);
18:   return 0;
19: }
```

# Solution to Exercise 3 (switch)

```c
#include <stdio.h>

int main(void) {
  char class = '\0';

  printf("Enter the class ID: ");
  scanf("%c", &class);
  switch (class) {
    case 'B':
    case 'b': printf("Battleship\n"); break;
    case 'C':
    case 'c': printf("Cruiser\n"); break;
    case 'D':
    case 'd': printf("Destroyer\n"); break;
    case 'F':
    case 'f': printf("Frigate\n"); break;
    default: printf("Unknow ship class %c\n", class);
  }
  return 0;
}
```